A. Einstein - 381
112 Mercer St
Princeton
New Jersey

Print that

May 7th,1942

Mr.Lazarus White,President, ASAHIT
~~American Society for the Advancement~~
~~of the Hebrew Institute of Technology~~
154 Nassau Str.
New York City

Dear Mr.White:

I am happy to extend to you my greetings on the occasion of the Second Anniversary of our Society. You know with what interest I have followed the fortunes of the new organization and I can say that you have accomplished a great deal in a short space of time.

The Hebrew Institute of Technology in Haifa is one of the key positions to the development of industries and every kind of practical work in Palestine and hence for the settlement of great numbers of Jews, who, as we expect, will find a haven in Palestine after this terrible war.

Our Jewish technical men,engineers,architects scientists and industrialists in America could hardly find a better and more fitting way to help solve the problem of Jewish refugees than by safeguarding the existence of the Institute,especially in these difficult times.

Let me thank you and all those who have helped to build up this new organization, by saying that it is a real joy for me to know that you and other technical men participate in this work. I for my part will give you all help possible.

Very sincerely yours,

A. Einstein

~~Professor Albert Einstein~~.

Die kinder benutzen nicht die
Lebenserfahrungen der Eltern;
die Nationen kehren sich nicht
um die Geschitchte. Die schlechten
Erfahrungen müssen immer wieder
aufs Neue gemacht werden.

Children do not use the life's
experiences of their parents: Nations
do not concern themselves with history.
The unfortunate experiences of the
past must always again be relived.

RE: EINSTEIN

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Die Kinder benutzen nicht die Lebenserfahrungen der Eltern, die Nationen kehren sich nicht um die Geschichte. Die schlechten Erfahrungen müssen immer wieder aufs Neue gemacht werden.

Albert Einstein.

12 XI. 23.

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2nd edition, 1944 $1.00

UCTION OF ELECTRICITY (facsimile of the rtrait, New York, 1945. $.50

ENGINEER, 8°; 8, 31 pp., 18 plates, wraps, $1.00, in cloth $2.00

8°, 16 pp., portrait, plates, New York, 1947. $.50

fragment from Schedel's Chronicle, Nurnberg, he Latin by Dr. Edward Rosen, folio, 24 pp., out of print

-MAGNETIC INDUCTION, 4°; 4, 31 pp., tter to Phillips, New York, 1949. $1.00

., boards, plates, one folding, New York, 1950. out of print
2nd edition, Norwalk, 1952 $1.50

t led to the Discovery of Useful Electricity, 4°, $1.00

of the Middle Ages and the Renaissance, folio, Dr. Edward Rosen and notes by Bern Dibner, $2.50

ON MUSCULAR MOTION, translation and 3. $6.00

HE ELECTRICAL SCIENCE, 48 pp., 10 parts, $1.00

Die Kinder benutzen nicht die Lebenserfahrungen der Eltern; die Nationen kehren sich nicht um die Geschichte. Die schlechten Erfahrungen müssen immer wieder aufs Neue gemacht werden.

Albert Einstein.

12 XI. 23.

Über eine naheliegende Ergänzung des Fundamentes der allgemeinen Relativitäts-Theorie.

Von A. Einstein.

H. Weyl hat bekanntlich die allgemeine Relativitäts-theorie durch Hinzufügung einer weiteren Invarianz-Bedingung zu ergänzen versucht und ist dabei zu einer Theorie gelangt, die schon ihres folgerichtigen und ~~des~~ kühnen mathematischen Aufbaues wegen ein hohes Interesse verdient. Diese Theorie ruht im Wesentlichen auf zwei Gedanken:

a) In der allgemeinen Relativitätstheorie kommt dem Verhältnis der Gravitations-Potential-Komponenten $g_{\mu\nu}$ eine erheblich ursprünglichere physikalische Bedeutung zu als den Komponenten $g_{\mu\nu}$ selbst. Denn der Inbegriff der von einem Weltpunkte ausgehenden Weltrichtungen, in denen Lichtsignale von ihm ausgehen können, der Lichtkegel, scheint uns mit dem Raum-Zeit-Kontinuum unmittelbar gegeben zu sein; dieser Lichtkegel ist aber durch die Gleichung

$$ds^2 = g_{\mu\nu}\, dx_\mu\, dx_\nu = 0$$

~~gegeben~~ bestimmt, in welche nur die Verhältnisse der $g_{\mu\nu}$ eingehen. Überhaupt gehen in die elektromagnetischen Gleichungen des Vakuums nur die Verhältnisse der $g_{\mu\nu}$ ein. Dagegen drückt ~~die~~ die durch die $g_{\mu\nu}$ selbst erst bestimmte Grösse ds keine blosse Eigenschaft des räumlich-zeitlichen Kontinuums aus; denn es bedarf zur Messung dieser Grössen eines materiellen Gebildes (Uhr). Deshalb liegt die Frage nahe: Lässt sich die Relativitätstheorie nicht abändern auf Grund der ~~auf die~~ Annahme ~~gründen~~, dass nicht der Grösse ds an sich sondern nur der Gleichung $ds^2 = 0$ eine invariante, d.h. ~~von~~ ~~der besonderen~~ physikalische Bedeutung zukomme? ~~Physikalisch lässt sich die Frage auch so formulieren: Lässt sich eine allgemeine Relativitätstheorie nicht aufbauen, ohne von Anfang an die Existenz von Masstäben und Uhren vorauszusetzen, die sich von ihrer Vorgeschichte unabhängig verhalten?~~

b) ~~Der~~ Der zweite ~~n~~ Gedanke ~~n~~ Weyls ~~bildet die~~ bezieht sich auf eine Methode der Verallgemeinerung der Riemann'schen Metrik sowie auf ~~deren~~ die physikalische Deutung der in ihr neu auftretenden Grössen φ_ν.

150

Der ~~gemeinsame~~ Gedanke lässt sich etwa so skizzieren. Metrik setzt Übertragung von
Strecken (Massstäben) voraus. Die Riemann'sche Geometrie setzt ferner voraus,
dass das Verhalten (Länge) eines Massstabes an einem Orte unabhängig davon sei,
auf welchem Wege er an diesen Ort gelangt ist; sie enthält also ~~genauer~~ die beiden
Voraussetzungen

I. Existenz übertragbarer Massstäbe
II. Unabhängigkeit von deren Länge vom Übertragungswege

Weyls Verallgemeinerung der Riemann'schen Metrik behält I bei, lässt hingegen
II fallen. Er lässt die Mess- Länge eines Massstabes von einem über den
Übertragungsweg erstreckten und von diesem im Allgemeinen abhängigen Integral

$$\int \varphi_\nu dx_\nu$$

abhängen, wobei die φ_ν Raumfunktionen sind, welche demgemäss ~~neben dem Verhalt~~ die
Metrik mitbestimmen. Bei der physikalischen Deutung der Theorie werden
dann die φ_ν mit den elektromagnetischen Potentialen identifiziert.

Bei aller Bewunderung der ~~logischen~~ Einheitlichkeit und
Schönheit des Weyl'schen Gedankengebäudes scheint mir dasselbe
der physikalischen Wirklichkeit gegenüber nicht standzuhalten. Wir
kennen keine zum Messen benutzbare Naturdinge deren relative
Ausdehnung von der Vorgeschichte abhinge. Auch scheint der von Weyl
eingeführten geradesten Linie sowie den in dieser und den übrigen
Gleichungen der Weyl'schen Theorie explizite auftretenden elektrischen
Potentialen keine unmittelbare physikalische Bedeutung zuzukommen.

Andrerseits aber scheint mir der unter a) dargelegte Weyl'sche
Gedanke ein glücklicher und natürlicher zu sein, wenn man auch
nicht a priori wissen kann, ob er zu einer brauchbaren physikalischen
Theorie zu führen vermag. Bei dieser Sachlage kann man sich fragen,
ob man nicht zu einer klaren Theorie gelangt. Indem man nicht
nur mit Weyl auf die Voraussetzung II sondern auch auf die Voraussetzung
I von der Existenz übertragbarer Massstäbe (bezw. Uhren) von vorneherein verzichtet.
Im Folgenden soll nun gezeigt werden, dass man zwanglos zu einer Theorie
gelangt, indem lediglich von der invarianten Bedeutung der Gleichung

$$ds^2 = g_{\mu\nu} dx_\mu dx_\nu = 0$$

ausgeht, ohne ~~Art~~ von dem Begriff des Abstandes ds (oder ~~physikalisch~~
ausgedrückt – ~~ohne~~ von den Begriffen Massstab und Mess-Uhr Gebrauch zu
machen.

Bei der Bemühung, eine solche Theorie aufzustellen, wurde ich
von Kollegen Wirtinger in Wien wirksam unterstützt. Ich fragte ihn,
ob es eine Verallgemeinerung der Gleichung der geodätischen Linie
gebe, in welcher nur die Verhältnisse der $g_{\mu\nu}$ eine Rolle spielen. Er ant-

wortete wir im folgenden Sinne.

Wir verstehen unter „Riemann-Tensor" bezw. „Riemann-Invariante" einen Tensor bezw. ~~eine~~ Invariante bezüglich beliebiger Punkt-Transformationen, deren Invarianz-Charakter unter der Voraussetzung der Invarianz von $ds^2 = g_{\mu\nu} dx_\mu dx_\nu$ gilt. Wir verstehen ferner unter „Weyl-Tensor" bezw. „Weyl-Invariante" vom Gewicht n einen Riemann-Tensor* bezw. eine Riemann-Invariante* ~~welcher~~ mit ~~der~~ folgender zusätzlichen Eigenschaft: der Wert der Tensorkomponente bezw. Invariante multipliziert sich mit λ^n, wenn man die $g_{\mu\nu}$ durch $\lambda g_{\mu\nu}$ ersetzt, wobei λ eine beliebige Funktion der Koordinaten ist. Diese Bedingung lässt sich symbolisch durch die Gleichung

$$T(\lambda g) = \lambda^n T(g)$$

ausdrücken. Ist nun J eine (nur von den $g_{\mu\nu}$ und ihren Ableitungen abhängige) Weyl-Invariante vom Gewichte -1, so ist

$$d\sigma^2 = J g_{\mu\nu} dx_\mu dx_\nu \quad \ldots (1)$$

eine Invariante vom Gewichte 0, d. h. eine Invariante, die nur vom Verhältnis der $g_{\mu\nu}$ abhängt. Die gesuchte ~~Inv~~ Verallgemeinerung der geodätischen Linie ist dann gegeben durch die Gleichung

$$\delta\left\{\int d\sigma\right\} = 0 \quad \ldots (2)$$

Diese Lösung setzt natürlich die Existenz einer Weyl-Invariante von der genannten Art voraus. Weyls Untersuchungen weisen den Weg zu <u>einer</u> solchen. Er hat nämlich gezeigt, dass der Tensor

$$\left.\begin{aligned} H_{iklm} &= R_{iklm} - \frac{1}{d-2}\left(g_{il}R_{km} + g_{km}R_{il} - g_{im}R_{kl} - g_{kl}R_{im}\right) \\ &\quad + \frac{1}{(d-1)(d-2)}\left(g_{il}g_{km} - g_{im}g_{kl}\right)R \end{aligned}\right\} (3)$$

ein Weyl-Tensor vom Gewicht 1 ist.) (Dabei ist R_{iklm} der Riemann'sche Krümmungstensor, $R_{km} = g^{il}R_{iklm}$ der durch einmalige Verjüngung aus demselben hervorgehende Tensor zweiten Ranges, R der durch nochmalige Verjüngung entstehende Skalar. Hieraus geht sogleich hervor, dass

$$H = H_{iklm}H^{iklm} \quad \ldots (4)$$

ein Weyl'scher Skalar vom Gewichte -2 ist. Es ist also

$$\mathfrak{J} = \sqrt{\mathfrak{H}} \quad \ldots\ldots(5)$$

eine Weyl'sche Invariante vom Gewichte −1. Dies Ergebnis in Verbindung mit (1) und (2) liefert eine Verallgemeinerung der geodätischen Linie nach der von Wirtinger angegebenen Methode. Natürlich ist für die Beurteilung der Bedeutung dieses Resultates und der folgenden die Frage von grosser Wichtigkeit, ob ~~dann~~ J die einzige Weyl'sche Invariante vom Gewicht −1 ist, in welcher keine höheren als zweiten Ableitungen der $g_{\mu\nu}$ vorkommen.–

Auf Grund des bisher Entwickelten ist es nun ein Leichtes, jedem Riemann-Tensor einen Weyl-Tensor zuzuordnen und damit auch, Naturgesetze in Form von Differentialgleichungen aufzustellen, die nur mehr von den Verhältnissen der $g_{\mu\nu}$ abhängen. Setzen wir

$$g'_{\mu\nu} = \mathfrak{J} g_{\mu\nu},$$

so ist

$$d\sigma^2 = g'_{\mu\nu}\, dx_\mu\, dx_\nu$$

eine Invariante, die nur mehr von den Verhältnissen der $g_{\mu\nu}$ abhängt. Alle Riemann-Tensoren, die aus $d\sigma$ als Fundamentalinvariante in üblicher Weise gebildet werden, ~~sind~~ (~~abhängig der $g_{\mu\nu}$~~) ~~Weyl-Tensoren vom Ran~~ (als Funktionen der $g_{\mu\nu}$ und Ableitungen aufgefasst) Gewichte 0. Symbolisch können wir dies so ausdrücken. Ist $T(g)$ ein Riemann-Tensor, der ausser von den $g_{\mu\nu}$ und deren Ableitungen auch von anderen Grössen, etwa den Komponenten $\mathfrak{f}_{\mu\nu}$ des elektromagnetischen Feldes abhängen kann, so ist $T(g')$, ~~ein~~ als Funktion der $g_{\mu\nu}$ und ihrer Ableitungen betrachtet, ein Weyl-Tensor vom Gewicht 0. Es entspricht also jedem Naturgesetz $T(g)=0$ der allgemeinen Relativitätstheorie ein Gesetz $T(g')=0$, in welches nur die Verhältnisse der $g_{\mu\nu}$ eingehen.

Noch deutlicher wird dies Ergebnis durch folgende Überlegung. Da in den $g_{\mu\nu}$ ein Faktor willkürlich bleibt, wird es möglich sein, diesen so zu wählen, dass überall

$$\cancel{\mathfrak{H} = \mathfrak{J}^2 = \text{konst}}\ \mathfrak{J}_0^2 \ldots\ldots(6) \qquad \mathfrak{J} = \mathfrak{J}_0 \cdots(6)$$

wird, wobei $\mathfrak{J}_0$ eine Konstante bedeutet. Dann ist $g'_{\mu\nu}$ bis auf einen konstanten Faktor gleich $g_{\mu\nu}$ und die Naturgesetze nehmen in der neuen Theorie wieder die Form

$$T(g) = 0$$

an. Die ganze Neuerung gegenüber der ursprünglichen Form der allgemeinen Relativitätstheorie besteht dann in dem Hinzutreten

V

der Differenzialgleichung (6), welcher die $g_{\mu\nu}$ genügen müssen.

~~Im Folgenden~~ Es sollte hier nur eine logische Möglichkeit dargelegt werden, die der Veröffentlichung wert ist, mag sie für die Physik brauchbar sein ~~für die Physik zutreffen~~ oder nicht. Ob das eine oder das andere ~~dies~~ der Fall ist, ~~oder nicht~~, müssen weitere Untersuchungen lehren, ebenso, ob ausser der Weyl-Invariante $J = \sqrt{K}$ noch andere in Betracht kommen.

Kurze Zusammenfassung: Es wird gezeigt, dass man entsprechend dem Weyl'schen Grundgedanken auf die objektive Existenz der Lichtkegel (Invarianz der Gleichung $ds^2 = 0$) allein eine Invarianten-Theorie gründen kann, die jedoch im Gegensatz zu Weyl's Theorie keine Hypothese über Streckenübertragung enthält, und in welcher die Potentiale φ_ν nicht explizite in die Gleichungen eingehen. Ob die Theorie auf physikalische Gültigkeit Anspruch erheben kann, müssen spätere Untersuchungen ergeben.

A. Einstein.

5000.-

Albert Einstein

eigenhänd. Handschrift aus dem Jahre 1920

Autograph Collection
Dr. Max Thorek

Number

Name EINSTEIN, ALBERT

Profession German-American Physicist and Mathematician

Born 1879

Died 1955

Date of Document No date

Contents of Folder Autogr. formulae on positions, velocities and energies of physical systems, interspersed with remarks in German. 1½pp., folio. Biography. Portrait. Explanatory note by

Note: Professor Daniel Q. Posin.

An Elementary Derivation of the Equivalence of Mass and Energy

by Albert Einstein (Institute for Advanced Study, Princeton, N. J.)

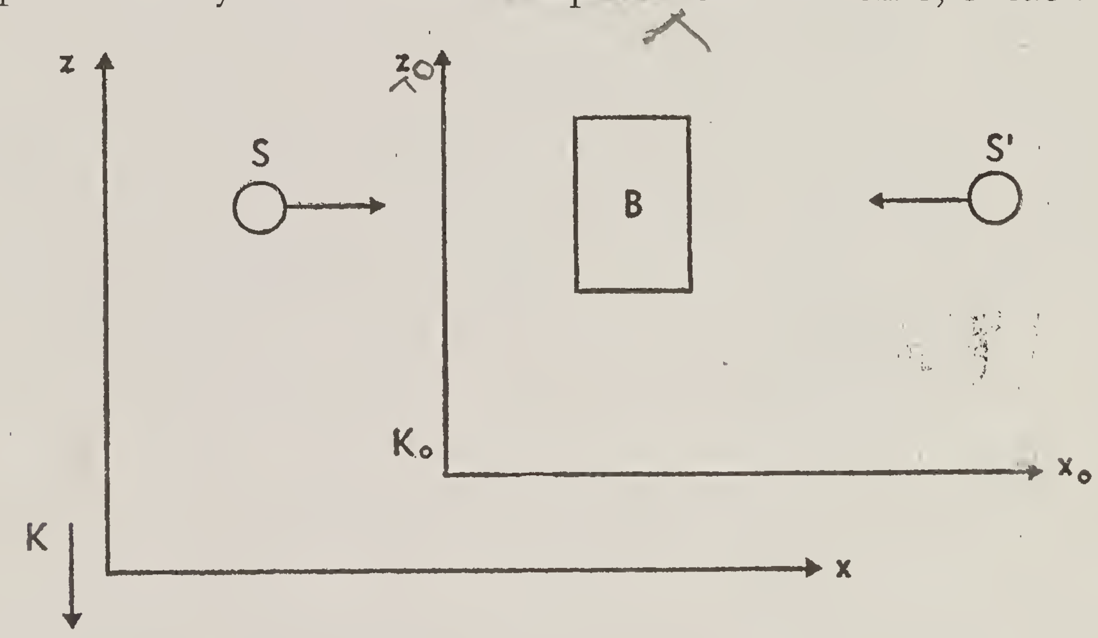
The following derivation of the law of equivalence which has not been published before, has two advantages. Although it makes use of the principle of special relativity, it does not presume the formal machinery of the theory but uses only three previously known laws:

(1) The law of the conservation of momentum.

(2) The expression for the pressure of radiation; that is, the momentum of a complex of radiation moving in a fixed direction.

(3) The well known expression for the aberration of light (influence of the motion of the earth on the apparent location of the fixed stars—Bradley).

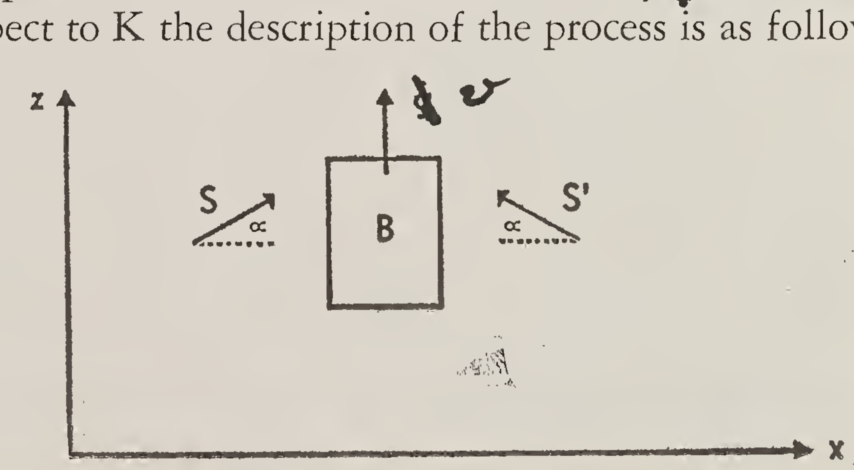
We now consider the following system. Let the body B rest freely in space with respect to the system K_0. Two ~~complexes~~ of radiation S, S' each of energy



$\frac{E}{2}$ move in the positive and negative x_0 direction respectively and are eventually absorbed by B. With this absorption the energy of B increases by E. The body B stays at rest with respect to K_0 by reasons of symmetry.

Now we consider this same process with respect to the system K, which moves with respect to K_0 with the constant velocity v in the negative z_0 direction. With respect to K the description of the process is as follows: / v

| v



EINSTEIN, ALBERT. Autogr. formulae on positions, velocoties and energies of physical systems, interspersed with remarks in German. 1½pp., folio. No place, probably written during the early time of his emigration.

Prof. Daniel Q. Posin is Professor of Physics at De Paul University. He was sent a copy of the enclosed material for analysis, and he states that the material deals with positions, velocities and energies of physical systems.

9

The body B moves in the positive z direction with velocity $\cancel{g}$. The two complexes of radiation now have directions with respect to K which make an angle α with the x axis. The law of aberration states that in the first approximation $\alpha = \frac{\cancel{g}}{c}$, where c is the velocity of light. From the consideration with respect to K_0 we know that the velocity $\cancel{g}$ of B remains unchanged by the absorption of S and S'. /v

Now we apply the law of conservation of momentum with respect to the z direction to our system in the coordinate-frame K.

I. *Before the absorption* let M be the mass of B; $M\cancel{g}$ is then the expression /v of the momentum of B (according to classical mechanics). Each of the complexes has the energy $\frac{E}{2}$ and hence, by a well known conclusion of Maxwell's theory, it has the momentum $\frac{E}{2c}$. Rigorously speaking this is the momentum of S with respect to K_0. However, when $\cancel{g}$ is small with respect to c, then the /v — more space momentum with respect to K is the same except for a quantity of second order of magnitude ($\frac{g^2}{c^2}$ comp. to 1). The z-component of this momentum is $\frac{E}{2c}$ sin α or with sufficient accuracy (except for quantities of higher order of magnitude) $\frac{E}{2c}$ or $\frac{E}{2}\cdot\frac{\cancel{g}}{c^2}$. S and S' together therefore have a momentum $E\frac{\cancel{g}}{c^2}$ /v /v in the z direction. The total momentum of the system before absorption is therefore

sin α

$\frac{E}{2c}\alpha$ or $\frac{E}{2}\cdot\frac{v}{c^2}$

$$M\cancel{g} + \frac{E}{c^2}$$ /v

II. *After the absorption* let M' be the mass of B. We anticipate here the possibility that the mass increased with the absorption of the energy E (this is necessary so that the final result of our consideration be consistent). The momentum of the system after absorption is then

$$M'\cancel{g}$$ /v

We now assume the law of the conservation of momentum and apply it with respect to the z direction. This gives the equation

$$M\cancel{g} + \frac{E}{c^2}\cancel{g} = M'\cancel{g}$$ /v /v /v

or

$$M' - M = \frac{E}{c^2}.$$

This equation expresses the law of the equivalence of energy and mass. The energy increase E is connected with the mass increase $\frac{E}{c^2}$. Since energy according to the usual definition leaves an additive constant free, so after suitable choice of the latter we may write for short

$$E = Mc^2.$$

April 6, 1959

Dear Dr. Thorek,

Thank you for your letter & enclosure.

I am glad that you find something of interest in an occasional program.

The material shown in the photostats deals with positions, velocities and energies of physical systems.

With every good wish,

Dan Q Posin

A. Einstein

Précieuse page autogr.
de formules – page d'étude
(fonctions Hamilton, etc ...)

1 ½ p. in F°

(datant, très probablement, de la
première période de l'émigration)

ALBERT EINSTEIN

1879 - 1955

German-American physicist and mathematician, was born in Ulm , of Jewish parentage. He studied at Zurich, and became a Swiss citizen. While holding a post in the Swiss Patent Office at Bern, he issued, in 1905, his first statement on the theory of relativity, later expanded in his <u>General Theory of Relativity</u>. This wrought fundamental changes in the theories the physicists held on the universe.

Einstein became professor of physics, first at Zurich, then at Prague. In 1914 he was made Director of the Kaiser Wilhelm Institute at Berlin-Dahlem. His international fame increased as his work in relativity, and his development of Planck's quantum theory, were defined by other scientists. He received the Nobel Prize in physics in 1921, after confirmations of his predictions of the nature of light were observed at the solar eclipse of 1920.

He published his great work on the Unified Field Theory in 1929, seeking to embrace mathematically the laws of magnetism and gravitation into a single formula, a combination of Maxwell's laws on electromagnetism and light, and Newton's laws on gravitation.

Einstein left Germany shortly before Hitler came to power in 1933. The Nazis stripped him of his German citizenship, which he had acquired when he became Director of the Kaiser Wilhelm Institute. Nations vied with each other to honor him. He became Head of the School of Mathematics at the Institute for Advanced Study at Princeton.

He was called one of the eight immortals of history, but he was an unassuming man. His violin was his chief form of recreation. His chief extracurricular interests were pacifism and Zionism.

But Michelson was well known to be no friend of relativity, the destroyer of the ether. Like so many, he was convinced that his own ill-fated experiments were the basis for the theory, and he explained the route in a talk given in 1927: The Michelson experiment had led Lorentz to propose the transformations, and "these contained the gist of the whole relativity theory."[155] Einstein reminisced later, "He told me more than once that he did not like the theories that had followed from his work,"[156] and he said he was a little sorry that his own work started this "monster."[157] Michelson was now seventy-nine years old, weak after a serious stroke that had first forced him to his sickbed two years earlier. The picture taken on that occasion (Fig. 1) shows the frail old man, standing next

Figure 1. *Michelson, Einstein, and Millikan at the California Institute of Technology, winter 1931. (Second row: W. S. Adams, W. Mayer, M. Farrand.) Courtesy Bernard Jaffe and Doubleday & Co., Inc.*

to Einstein, with his usual erect dignity on this last public appearance; but he was marked for the death that came three months later.

Among others present at a grand dinner in the new Athenaeum on 15 January 1931[158] were the physicists and astronomers C. E. St. John, W. W. Campbell, R. A. Millikan, W. S. Adams, R. C. Tolman, G. E. Hale, and E. P. Hubble, as well as Mrs. Einstein and two hundred members of the California Institute Associates. Millikan set the stage with his opinion concerning the characteristic features of modern scientific thought (it takes, "as its starting point, well-authen-

[155] Michelson, in "Conference on the Michelson-Morley Experiment," p. 344.
[156] Shankland, "Conversations," p. 57.
[157] *Ibid.*, p. 56.
[158] The proceedings were published in *Science*, 1931, 73: 375–381. All quotations below are from this source unless otherwise identified.

G. HOLTON, ISIS, Summer, 1969

A. A. MICHELSON ALBERT EINSTEIN ROBERT A. MILLIKAN

W. S. ADAMS W. MAYER M. FARRAND

CATALOGUE

OF

The Property of Victor Frank, Esq.

175 EINSTEIN (ALBERT, *scientist*) Interesting series of 9 typed Ls.s. in German to Professor Simon Frank (formerly professor of philosophy in St. Petersburg and Moscow). 10 *pp., 4to, Berlin.* 8 *April* 1929 *to* 12 *November* 1930. *with one three-line autograph note and three small autograph corrections*

*** Almost entirely concerned with Einstein's attitude to the Soviet régime. In the spring of 1929 he was approached both by White Russian and by Soviet emissaries. The former sought his support for a charitable scheme on behalf of impoverished refugees, the latter wanted him to encourage émigré scientists and others to return to Russia. He turned to Professor Frank for advice. In the earlier letters Einstein tries to maintain an impartial balance between White and Red. He sees the tragedy of historical developments and he is aware that "no bridges can be built over the abyss of suffering", but he looks upon the Soviet régime as fanatical rather than evil. Only in the last letter, after more and more evidence of political trials had begun to reach Western Europe, does he agree that Professor Frank has been right all along:

> . . . the Russian authorities are for political reasons putting innocent men to death on false charges, in order to find scapegoats for their own failures . . . I need not tell you that I absolutely condemn these methods. And I am convinced that no good goal can possible be reached by them . . . [partial translation]

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Princeton N.J.,July 28,1969
112 Mercer Str.

Mr.Bern Dibner
Burndy Library
Norwalk,Conn.

Dear Mr.Dibner:

In reply to your inquiry of July 25th I enclose a copy of a Sotheby Catalogue of 1967 which gives you the data about Professor Simon Frank. The latter's son apparently sold the letters and we were able to secure copies of the handwritten one, from the buyer, a Japanese dealer. As I have the original carbon copy and the xerox-copy of the letter of May 2,1929 in the files I am returning the copy you sent me with my thanks.

The "Verein" mentioned in the letter is,or was, the "Verein der Russischen Juden im Auslande". Professor Einstein had been asked to lend his name to some charity-undertaking of that society and -not knowing much about it-had asked Professor Frank for information.

I hope this information is of service to you; I thank you also for offering your own services. I may some day avail myself of them.

Yours very sincerely,

Helen Dukas

Helen Dukas

encl.

CONDITIONS IN STALINIST RUSSIA

58 EINSTEIN, Albert. TLS, 1p., 4to, Berlin, May 2, 1929. To Professor Frank. In German with full English translation. Fine conditon. $250.00

"I thank you...for the friendly clarification in matters of the Russian Union, upon which I have guided myself completely. I am convinced that previously I was given bad advice....your passionate statements on the question of traveling back have made a great impression on me, especially your resigned offer to serve as test object yourself. In a flash one sees the whole tragedy of the development surface before him and one grasps that there are no bridges over the abyss of passion. What you perceive as evil and tyranny is probably fanaticism in connection with distrust. In any case however I see that I have not correctly represented to myself the difficulties of such an action...."

Kingston -69

President of the Royal Commission for the Paris Universal Exhibition of 1878. He thanks Huntly for his work as a member of the International Jury. He is having prepared a copy of the List of Awards, however, he wishes to further express his gratitude by sending his portrait, "as a personal mark of our connection in the work of the Paris Exhibition, which has been attended with such satisfactory results.

54. EDWARD VIII. King of England; abdicated. ALS, 1-1/2pp., 8vo, Magdalen College, Oxford, November 19, 1912. To Madame Bricker. Fine early letter, written in French, mentioning that he enjoys the life at Oxford very much. $45.00

DSI

55. EDWARD VIII. Unusually fine reproduction of a sketch of Edward, 5-3/4 by 4-1/4 inches, plus wide margins, bearing a large bold signature in a light portion of the photograph. Fine condition. $47.50

$$\frac{\partial \mathfrak{E}}{\partial q_\nu} = \dot p_\nu \qquad \frac{\partial \mathfrak{E}}{\partial p_\nu} = \dot q_\nu \qquad\qquad p_\nu = \frac{\partial S}{\partial q_\nu}$$

$$\frac{\partial \mathfrak{E}}{\partial q_\nu} = -\frac{\partial^2 S}{\partial q_\nu \partial q_\mu} \frac{\partial \mathfrak{E}}{\partial p_\mu} \left(-\frac{\partial S}{\partial t}\right) = \frac{\partial \mathfrak{E}}{\partial}$$ | erste Gl. erfüllt, zweite Gl. def. $\dot q_\nu$

Wenn für p_ν der $\mathfrak{E}$ Ausdr. in S eingesetzt, so ist dies Diff. Gl. 2. Ordnung für S.

$$\frac{dH}{dt} = \underbrace{\frac{\partial H}{\partial p_\nu} \cancel{\frac{dp_\nu}{dt}} + \frac{\partial^2 S}{\partial q_\nu \partial q_\mu} \frac{dq_\mu}{dt}}_{-\frac{\partial H}{\partial q_\mu}} + \frac{\partial H}{\partial q_\mu} \frac{dq_\mu}{dt}$$

$$\frac{d}{dq_\nu}\left[\mathfrak{E}\right] = 0$$ Ist äquivalent $\mathfrak{E} = \text{konst}$?

Ist gewöhnl. Diff. Gl. 1. Ordnung für S.

$i=1\ k=2$	$\eta_{2tr}\ \eta_{1sr'}$		$-\psi_{23}\,\psi_{31}$	$-2\psi_{13}\psi_{23} + 2\psi_{12}\psi_{33}$
	1 3	2 3		
$\psi_{rs}\psi_{r't}$	1 3	3 2	$+\psi_{33}\,\psi_{12}$	
	3 1	2 3	$+\psi_{12}\,\psi_{33}$	
	3 1	3 2	$-\psi_{13}\,\psi_{23}$	

$$(\delta_{sk}\delta_{rr'} - \delta_{sr'}\delta_{rk})\psi_{ri}\psi_{r's} - (\delta_{ss}\delta_{rr'} - \delta_{sr'}\delta_{rs})\psi_{ri}\psi_{r'k} + (\delta_{it}\delta_{rr'} - \delta_{ir'}\delta_{rt})\psi_{irt}\psi_{ir'k}$$

$$\psi_{r'i}\psi_{r'k} - \psi_{ik}\psi_{ss} - 3\psi_{ri}\psi_{rk} + \psi_{si}\psi_{sk} + \psi_{ri}\psi_{rk} - \psi_{itt}\psi_{ik}$$ | hebt sich.

Bleibt $\quad 1\,1 \mid 2\psi_{23}\psi_{23} - 2\psi_{22}\psi_{33}$

$\quad 1\,2 \mid -2\psi_{13}\psi_{23} + 2\psi_{12}\psi_{33}$

Die anderen Gl. ergeben $-2\delta_{ik}\psi_{rs}^2 + 2\psi_{ir}\psi_{kr} + \psi_{ir}\psi_{kr} + \psi_{r}\psi_{r,ik} - \psi_{r}\psi_{rik} + \psi_{r}\psi_{rik} + \psi_{rs}\psi_{rk}$

$$- \psi_{r}\psi_{rik} - \psi_{ri}\psi_{rk} - \psi_{r}\psi_{rik}$$

$$\boxed{-\psi_{r}\psi_{rik} - 3\psi_{r,i}\psi_{r,k} - 2\delta_{ik}\psi_{rs}^2}$$

Alle Zus. Gl. $\quad 1\,1 \mid 2\psi_{23}\psi_{23} - 2\psi_{22}\psi_{33} - \psi_{r}\psi_{r11} - 3\psi_{r1}\psi_{r1} - 2\psi_{rs}^2$

$\quad 1\,2 \mid -2\psi_{13}\psi_{23} + 2\psi_{12}\psi_{33} - \psi_{r}\psi_{r12} - 3\psi_{r1}\psi_{r2} - 2\psi_{rs}^2$

$$2\psi_{23}\psi_{23} - 2\psi_{22}\psi_{33} - 3\psi_{21}\psi_{21} - 3\psi_{31}\psi_{31} \cancel{- 2\psi_{11}^2 - 2\psi_{22}^2 - 2\psi_{33}^2 - 4\psi_{12}\psi_{12} - 4\psi_{23}\psi_{23} - 4\psi_{31}\psi_{31}}$$

$$-\psi_1\psi_{111} - \psi_2\psi_{211} - \psi_3\psi_{311}$$

$$-3\psi_{r1}\psi_{r1} + 3\psi_{11}\psi_{11} + 2\psi_{23}\psi_{23} - 2\psi_{22}\psi_{33} - 2\psi_{rs}^2$$

$\overline{U_{ik}}$

Angesetzt Var. Prinzip für $\delta\int g^{ik}\left(\Gamma^{s}_{ik,s} - \Gamma^{s}_{i\,}{}_{,}\Gamma^{\alpha}_{sk} - \underline{\Gamma^{s}_{is,k}}^{\,\ell ik} + \Gamma^{s}_{ik}\, l_{,s}\right)$

Erstere Diff. Gl. vorausgesetzt liefert $g_{\underset{+-}{ik};s} = 0$ und $U_{ik} \underset{-\frac{1}{2}g_{ik}U}{=} 0$ (oder $R_{ik} \underset{\frac{1}{2}g_{ik}U}{=} 0$)

Wenn $g - \Gamma$ Gl. von vornherein angenommen werden, dann ist kein Unterschied zwischen beiden Hamilton-Funktionen.

Es gilt also mit $g_{\underset{+-}{ik};s} = 0$ $\quad \delta\int g^{ik} R_{ik} = 0$

Variation des letzteren gibt zunächst $\quad (g^{\underset{+-}{ik}}{}_{;s})\,\delta\Gamma^{s}_{ik} + \overset{+g^{is}\Gamma_s}{g^{ik}{}_{,k}}\,\delta\underline{\Gamma^{s}_{i\,s}} + \delta g^{ik} R_{ik}$

$$\cancel{g^{ik}{}_{,k} + g^{ik}\Gamma^{s}_{ik}\left(+g^{is}\Gamma^{k}_{ks} - g^{ik}\underline{\Gamma^{s}_{ks}}\right)}$$

$$-g^{is}\Gamma_s$$

$$0 = \delta g^{ik} R_{ik} + g^{is}\Gamma_s\,\delta\underset{\delta\frac{W_i}{W}}{\underline{\Gamma^{s}_{i\,s}}} = 0$$

May 5,1946

Mr.Judah Wattenberg
154 Nassau Str.
New York 7,N.Y.

Dear Mr.Wattenberg:

I have written a short paper (about 2 pages) for your year-book, containing an elementary proof for the mass-energy formula which has not been published before and which seems to me ~~very~~ interesting. I shall send it to you as soon as my assistant has translated it into English.

Sincerely yours,

A. Einstein.

Albert Einstein.

ALBERT EINSTEIN

250/-
ne

BERLIN W. den 2. Mai 1929
HABERLANDSTR. 5

Sehr geehrter Herr Professor Frank!

Ich danke Ihnen sehr für die freundliche Aufklärung in Sachen des russischen Vereins, nach der ich mich vollständig gerichtet habe. Ich bin überzeugt, dass ich vorher von verleumderischer Seite schlecht beraten war.-

Ihre leidenschaftlichen Ausführungen zur Rückwanderungsfrage haben grossen Eindruck auf mich gemacht, besonders das resignierte Anerbieten, selbst als Versuchsobjekt zu dienen. Die ganze Tragik der Entwicklung sieht man blitzartig vor sich auftauchen und man begreift, dass es über die Abgründe der Leidenschaft keine Brücken gibt. Was Sie als Schlechtigkeit und Tyrannei empfinden, ist wahrscheinlich Fanatismus in Verbindung mit Misstrauen. Jedenfalls aber sehe ich, dass ich mir von den Schwierigkeiten einer solchen Aktion keine richtige Vorstellung gemacht habe.-

Es grüsst Sie freundlichst und mit bestem Dank für Ihre unbeschränkte Aufrichtigkeit

Ihr

A. Einstein

April 9,1948

RECEIVED
APR 13 1948

Mr.Judah Wattenberg
American Technion Society
154 Nassau Str.
New York 7,N.Y.

Dear Mr.Wattenberg:

I am very sorry not to be able to write the article you requested. I have simply not the time to write something worthwhile and I do not wish to write something mediocre.

Yours very sincerely,
A. Einstein.
Albert Einstein.

DS

November 5,1943

Mr.Judah Wattenberg
154 Nassau Str.
New York City

My dear Mr.Wattenberg:

I cannot quite agree with your interpretation of Mr.Zemurray's letter of October 20th. It seems to me that he does not wish to become Co-Chairman of the Kisch Memorial Committee and,therefore, I cannot write him again insisting on his acceptance. If your believe that really only modesty was the cause of his refusal and that it would be possible to win him over for the chairmanship this could be done only through oral conversation.

Sincerely yours,

A. Einstein.

Professor Albert Einstein.

THE INSTITUTE FOR ADVANCED STUDY
SCHOOL OF MATHEMATICS
PRINCETON, NEW JERSEY

May 31, 1946

Mr. Judah Wattenberg
154 Nassau Str.
New York 7, N.Y.

Dear Mr. Wattenberg:

Enclosed I am returning the proofs, I agree with the substitution of "parcel" for "complex" if it seems preferrable to Dr. Darrow. (I have not corrected the word in the proof.) I agree too with the substitution of "momentum" for "impulse".

The only thing I have corrected in the proof was to substitute v for the letter g as sign for the velocity. The reason is that the use of g for a velocity is contrary to usage (in my manuscript I have used the letter q - not g). I have now substituted v to avoid any possibility of confusion.

Sincerely yours,

A. Einstein.

Albert Einstein.

June 22,1946

Mr.Judah Wattenberg
Editor,Technion Journal
154 Nassau Str.
New York City

Dear Mr.Wattenberg:

thank you very much for your justified remark in your letter of June 20th. It would be good if you would be kind enough to make the correction in the copies not yet mailed. If,however, this should make too much trouble the correction could also be left to the understanding reader.

Sincerely yours,

A. Einstein

Albert Einstein.

June 9,1947

Mr.Judah Wattenberg
154 Nassau Str.
New York 7,N.Y.

Dear Mr.Wattenberg:

My sincere thanks for the seeds from Palestine you were so kind to send me. I shall try to give them occasion for further development. I am glad that the Technion has developed at least as well as my symbolic contribution to it.

With kind regards,

sincerely yours,

A. Einstein.

Albert Einstein.

Einstein, Albert (1879-1955)

172. EINSTEIN, ALBERT. German-American physicist; author of the Theory of Relativity. Magnificent Typed Letter Signed, in English. 2pp., 4to. Princeton, Feb. 18, 1955. To Irwin Edelman, Los Angeles. An extraordinary exposition of Einstein's mathematical-philosophical method. "...I want to give you a more complete outline of my criticism of the triad thesis-antithesis-synthesis....I shall restrict myself to the purely logical consideration....The thesis then consists of an axiom or several axioms upon which logical consequences are supposed to be based. The anti-thesis...is a proposition which is in logical contradiction to the thesis but which...for some reasons, is regarded as true (f.i., an empirical proposition). Under those circumstances the thesis must be discarded as useless. What is now defined as 'synthesis' is not a legimate product of thesis and anti-thesis...rather the postulation of a new axiom...or, in short, the basis of a new theory (which excludes the former one). The whole, therefore, is not a logical process....The supposition of all-pervading laws reflects the possibility of something new <u>in principle</u> as suggested by 'synthesis'. The whole thing is a nightmare...." We agree, Amen!! Unusually fine, if not a bit complicated! 500.00

Richards '70

Not located or identif., 1983, by Ellells:
Clipped by Dr. D. for interest, rather than purchased?

Paul C. Ri

Autograph

233 HARVARD

BROOKLINE, MASS.

ADDRESS CORRECTION

Third Class Mail

EINSTEIN, ALBERT (1879-1955) Famous physicist (Theory of Relativity)

Autograph Correcpondence Card, signed in German to Frau Weineck, Prague (1925) £8/8/-
Regretting that he could not handle the business she suggested. Einstein worked with Dr. Ladislaus Weineck in Prague (1898-1913)

Mr. Bern Dibner,

The Burndy Lib

Norwalk,

Conn. U.S.

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me and address: Mrs.

22, Buckingh

IR LETTER SHOU
IRE ; IF IT DOES
OR SENT BY C

Absender:

Sehr geehrte Frau Weineck!

Leider kann ich mich mit der von Ihnen genannten Angelegenheit nicht befassen.

Hochachtungsvoll

A. Einstein.

Postkarte

Frau

H. Weineck

Bubenc ul. 362

Prag (Tschechoslowakei)

C154 (4. 24)

Postkarte

Frau

H. Weineck

Bubna ul 362

Prag (Tschechoslowakei)

C154 (4.24)

Sehr geehrte Frau Weineck!

Leider kann ich mich mit der von Ihnen genannten Angelegenheit nicht befassen.

Hochachtungsvoll

A. Einstein.

Absender:

Albert Einstein. 1928.

Albert Einstein.

AUTOGRAPHE

de

Einstein

Albert

OBSERVATIONS

2) L. a. s. 1/2 p. 4° – 4. XI. 1926 gerichtet an Dr. Weiner, Brünn, erkundigt sich, wer „dieser [illegible]" (es handelt sich um die eigenhändige Niederschrift der Arbeit „Über eine neue

[illegible] fundamentales

[illegible] [The]orie") in

[illegible] kann

[illegible] seiner Ver-

4) L.a.s. 1 1/2 p. 4, o.O., 7.11. 1931, an Herrn Prof. Osvald Veblen, der Univ. Princeton, dem er die von ihm und seinem Assist. W. Mayer gefundenen Lösung des „Elektrizitätsproblems" bekanntgibt, die demnächst im Druck erscheinen soll. / Gemeint ist jedenfalls seine neue Theorie der Feldgleichungen, welche im November 1931 der Akad. d. Wissensch. in Berlin vorgelegt wurde /. Er setzt seine Theorie in mathemat. Entwicklung auseinander und schreibt am Schluss: „Jedenfalls bin ich davon überzeugt, dass der eingeschlagene Weg, der aber zunächst die Theorie der Materie noch nicht ohne weiteres liefert, der richtige ist."

[...]be von
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5) L.s. 1 p.4, Berlin, 18.9.1930, an Dr. Weiner, Brünn, dankt für die Uebersendung eines Machbriefes und spricht über seine Beziehungen zu Mach und dessen Stellungnahme zur Relativitätstheorie.

Geb. 14. III. 1879 in Ulm a/Donau, besuchte Elementarschule u. Luitpoldgymnasium München, in [illegible] Jahren [illegible] als Oberquintaner [illegible]. 1894 Familienübersiedlung nach Mailand, 1/2 Jahr ohne Schulbesuch, Beschäftigung mit Literatur, auf großen Ausflügen u. Wanderungen in Italien, dann Versuch des Eintrittes am Polyt. Zürich, wegen ungenügender Vorkenntnisse in Naturwissenschaften u. Sprachen Kantonsschule in Aarau, wo er maturierte. Schon da Beschäftigung mit der Optik bewegter Körper. 1896 – 1900 Stud. am Polyt. Z. Abteilung für das Lehramt, dann vergebliche Versuche Assistent für Math. od. Physik zu werden; Privatlehrer in Schaffhausen u. Bern, 1903 mit serb. Studentin verheiratet, Ehe bald getrennt. 1901 Züricher Bürgerrecht erworben. 1902 durch seinen Univ. Kollegen u. Freund M. Grossmann als Vorprüfer Patentamt Bern unter Direktor Haller bis 1909. Doktordiss. 1905, „Über eine neue Bestimmung der Moleküldimensionen", dann Privatdozent in Bern, 1909 Extraord. f. theor. Phys. Univ. Zürich, 1911 Ordin. in Prag, 1912 Ordin. Polyt. Zürich, 1914 Berlin, Mitglied d. Akad. der Wissenschaften mit Lehrauftrag a/d. Universität.

AUTOGRAPHE

de

Einstein

Albert

OBSERVATIONS

2) L. a. s. 1/2 p. 4° 4.XI.1926 gerichtet an Dr. Weiner, Brünn, erkundigt sich, wer „dieses Manuskript" (es handelt sich um die eigenhändige Niederschrift der Arbeit „Über eine naheliegende Ergänzung des Fundamentes der allgem. Relativitätstheorie") in den Handel gebracht haben könnte. Eröffnet die Möglichkeit einer Professur in Brünn.

3) P.a. o.O.u.D. /nach Angabe von Prof. Ehrenfest etwa 1925 /, 1 Seite 4°. Die Grundgleichungen der Relativitätstheorie, welche sich Einstein gelegentlich eines Vortrages in Leyden auf dieses Blatt niedergeschrieben hat. Auf der Rückseite 5 Punkte als Notizen für einen Vortrag von der Hand Prof. Ehrenfests. Geschenk von Prof. Ehrenfest an A.W. /

Geb. 14.III.1879 in Ulm a/d Donau, besuchte Elementarschule u. Luitpoldgymnasium München, in drei Jahren er als Obersekundaner austrat. 1894 Wohnsitzverlegung nach Mailand, 1/2 Jahr ohne Schulbesuch, Beschäftigung mit Literatur, auf großen Ausflügen u. Wanderungen in Italien, dann Versuch des Eintritts am Polyt. Zürich, wegen ungenügender Vorkenntnisse in Naturwissenschaften u. Sprachen Kantonsschule in Aarau, wo er maturierte. Schon da Beschäftigung mit der Optik bewegter Körper. 1896-1900 Stud. am Polyt. Z. Abteilung für das Lehramt, dann vergebliche Versuche Assistent für Math. od. Physik zu werden; Privatlehrer in Schaffhausen u. Bern, 1903 mit phys. Studentin verheiratet, Sohn Albert geboren. 1901 Züricher Bürgerrecht erworben. 1902 durch seinen Univ. Kollegen u. Freund M. Grossmann als Vorprüfer Patentamt Bern unter Direktor Haller bis 1909. Doktordiss. 1905, „Über eine neue Bestimmung der Moleküldimensionen" dann Privatdozent in Bern, 1909 Extraord. f. theor. Phys. Univ. Zürich, 1911 Ordin. in Prag, 1912 Ordin. Polyt. Zürich, 1914 Berlin, Mitglied d. Akad. der Wissenschaften mit Lehrauftrag a/d. Universität.

AW

150

2. XI. 31.

Lieber Herr Veblen!

Ich bin sehr neugierig auf Eure Lösung des Elektrizitätsproblems. Die Lösung von Herrn W. Mayer und mir beruht auf Folgendem.

Wir haben im vierdimensionalen Raum neben den Vierervektoren (a^s) Fünfervektoren a^σ eingeführt, welche mit den Vierervektoren gemäss einer linearen Beziehung

$$a^s = \gamma_\sigma{}^s a^\sigma$$

zusammenhängen. Für die a^σ ist ein infinitesimales Verschiebungsgesetz eingeführt:

$$\delta a^\sigma = -\Gamma_{\iota s}^{\sigma} a^\iota dx_s . \left(a^\sigma{}_{;t} = \frac{\partial a^\sigma}{\partial x_t} + a^\alpha \Gamma_{\alpha t}^{\sigma} \right)$$

Es gibt eine „Fünfer-Metrik", welche charakterisiert ist durch

$g_{\iota\kappa} a^\iota a^\kappa$, und wobei $g_{\iota\kappa;s} = 0$.

Es gibt im vierdimensionalen Raum Linien, deren Elemente „fünfer-parallel" sind. Dies sind die Bewegungsgleichungen elektrisch geladener Massenpunkte. Die Γ sind definiert durch die Gleichung

$$\gamma^\iota{}_{r;q} = A^\iota F_{rq}$$

Hiebei ist F_{rq} antisymmetrisch und spielt die Rolle des elektromagnetischen Feldes. A^ι ist jener Fünfervektor, welcher durch die Gleichungen

$$\gamma_\iota{}^s A^\iota = 0 \; ; \; g_{\iota\kappa} A^\iota A^\kappa = 1$$

charakterisiert sind.

die T_k^i's geben Anlass zur Bildung einer Fünfer-Krümmung, welche mit den Feldgleichungen etwa so zusammenhängt wie die Viererkrümmung mit den alten Gleichungen des reinen Gravitationsfeldes.

Wenn die Arbeit gedruckt ist, senden wir Ihnen sogleich ein Exemplar. Die Theorie stammt psychologisch von der von Kaluza ab, vermeidet aber den fünfdimensionalen Raum. Es wäre sehr wunderbar, wenn wir unabhängig voneinander auf dieselbe Methode gekommen wären. Jedenfalls bin ich davon überzeugt, dass der eingeschlagene Weg, der aber zunächst die Theorie der Materie noch nicht ohne Weiteres liefert, der richtige ist.

Herzlich grüsst Sie

Ihr A. Einstein.

P. S. Wahrscheinlich komme ich in nächster Zeit nicht nach Amerika.

1

DSI

4. XI. 26.

Herrn Dr. Weiner, Brünn.

Sehr geehrter Herr Doktor!

Ich habe Ihren liebenswürdigen Brief an Herrn Blumenfeld gelesen und erinnere mich gut Ihrer früheren Einladung, der ich damals leider nicht Folge leisten konnte. Wer mag wohl dies Manuskript in den Handel gebracht haben? Wenn Sie es sagen dürfen und können, wäre es mir lieb. Ich verspreche Ihnen, ~~es~~ Ihre Mitteilung für mich zu behalten, d. h. keinen Gebrauch davon zu machen. Vielleicht kann ich Sie doch einmal besuchen, um das früher Versäumte nachzuholen.

Es grüsst Sie freundlich

Ihr

A. Einstein.

(1)

January 8th, 1947

Dr. Walter Dill Scott
Chairman Editorial Board
Nelson's Encyclopedia
153 N. Michigan Avenue
Chicago 1, Ill.

My dear Dr. Scott:

I am sending you enclosed the article about the theory of relativity as agreed upon. I should be obliged, however, if you would agree to some modification with regard to the mode of payment. My assistant, Mr. Ernst G. Straus, has made the English translation from the original German text and I have promised him 100 $ for his work. I should be obliged, therefore, if you would send me $ 400.- and $ 100.- directly to Mr. Ernst G. Straus, Institute for Advanced Study, Princeton N.J.

I have to apologize for the fact that the article is somewhat longer as you have requested. But I found it absolutely impossible to give a clear idea of the matter in a shorter time and in a simple language.

Yours very sincerely,
A. Einstein
Albert Einstein.

encl.

The Essence of the Theory of Relativity

by

Albert Einstein
Institute for Advanced Study
Princeton, N.J.

Mathematics deals exclusively with the relations of concepts to each other without consideration of the objects of experience. Physics too deals with mathematical concepts; however, these concepts attain physical content only by the clear determination of their relation to the objects of experience. This in particular is the case for the concepts of motion, space, time.

The theory of relativity is that physical theory which is based on a consistent physical interpretation of these three concepts. The name "theory of relativity" is connected with the fact that motion from the point of view of possible experience always appears as the <u>relative</u> motion of one object with respect to another (e.g., of a car with respect to the ground, or the earth with respect to the sun and the fixed stars). Motion is never observable as "motion with respect to space" or, as it has been expressed, as "absolute motion." The "principle of relativity" in its widest sense is contained in the statement: The totality of physical phenomena is of such a character that it gives no basis for the introduction of the concept of "absolute motion"; or shorter but less precise: There is no absolute motion.

It might seem that our insight would gain little from such a negative statement. In reality, however, it is a strong restriction for the (conceivable) laws of nature. In this sense there exists an analogy between the

theory of relativity and thermodynamics. The latter too is based on a negative statement: "There exists no perpetuum mobile."

The development of the theory of relativity proceeded in two steps, "special theory of relativity" and "general theory of relativity." The latter presumes the validity of the former and is its consistent continuation.

A. Special theory of relativity.

Physical interpretation of space and time in classical mechanics.

Geometry, from a physical standpoint, is the totality of laws according to which rigid bodies mutually at rest can be placed with respect to each other (e.g., a triangle consists of three rods whose ends touch permanently). It is assumed that with such an interpretation the Euclidean laws are valid. "Space" in this interpretation is in principle an infinite rigid body (or skeleton) to which the position of all other bodies is related (body of reference). Analytic geometry (Descartes) uses as the body of reference, which represents space, three mutually perpendicular rigid rods on which the "coordinates" (x, y, z) of space points are measured in the known manner as perpendicular projections (with the aid of a rigid unit-measure).

Physics deals with "events" in space and time. To each event belongs, besides its place coordinates x, y, z, a time value t. The latter was considered measurable by a clock (ideal periodic process) of negligible spatial extent. This clock C is to be considered at rest at one point of the coordinate system, e.g., at the coordinate origin (x = y = z = 0). The time of an event taking place at a point P(x, y, z) is then defined as the time shown on the clock C simultaneously with the event. Here the concept "simultaneous" was assumed as physically meaningful without special definition. This is a lack of exactness which seems harmless only since with the help of light (whose velocity

is practically infinite from the point of view of daily experience) the simultaneity of spatially distant events can apparently be decided immediately.

The special theory of relativity removes this lack of precision by defining simultaneity physically with the use of light signals. The time t of the event in P is the reading of the clock C at the time of arrival of a light signal emitted from the event, corrected with respect to the time needed for the light signal to travel the distance. This correction presumes (postulates) that the velocity of light is constant.

This definition reduces the concept of simultaneity of spatially distant events to that of the simultaneity of events happening at the same place (coincidence), namely the arrival of the light signal at C and the reading of C.

Classical mechanics is based on Galileo's principle: A body is in rectilinear and uniform motion as long as other bodies do not act on it. This statement cannot be valid for arbitrary moving systems of coordinates. It can claim validity only for so-called "inertial systems". Inertial systems are in rectilinear and uniform motion with respect to each other. In classical physics laws claim validity only with respect to all inertial systems (special principle of relativity).

It is now easy to understand the dilemma which has led to the special theory of relativity. Experience and theory have gradually led to the conviction that light in empty space always travels with the same velocity c independent of its color and the state of motion of the source of light (principle of the constancy of the velocity of light -- in the following referred to as "L-principle"). Now elementary intuitive considerations seem to show that the same light ray <u>cannot</u> move with respect to all inertial systems with the same

velocity c. The L-principle seems to contradict the special principle of relativity.

It turns out, however, that this contradiction is only an apparent one which is based essentially on the prejudice about the absolute character of time or rather of the simultaneity of distant events. We just saw that x, y, z and t of an event can, for the moment, be defined only with respect to a certain chosen system of coordinates (inertial system). The transformation of the x, y, z, t of events which has to be carried out with the passage from one inertial system to another (coordinate transformation), is a problem which cannot be solved without special physical assumptions. However, the following postulate is exactly sufficient for a solution: <u>The L-principle holds for all inertial systems</u> (application of the special principle of relativity to the L-principle). The transformations thus defined, which are linear in x, y, z, t, are called Lorentz transformations. Lorentz transformations are formally characterized by the demand that the expression

$$dx^2 + dy^2 + dz^2 - c^2dt^2,$$

which is formed from the coordinate-differences dx, dy, dz, dt of two infinitely close events, be invariant (i.e., that through the transformation it goes over into the <u>same</u> expression formed from the coordinate differences in the new system).

With the help of the Lorentz transformations the special principle of relativity can be expressed thus: The laws of nature are invariant with respect to Lorentz-transformations (i.e., a law of nature does not change its form if one introduces into it a new inertial system with the help of a Lorentz-transformation on x, y, z, t).

The special theory of relativity has led to a clear understanding

of the physical concepts of space and time and in connection with this to a recognition of the behavior of moving measuring rods and clocks. It has in principle removed the concept of absolute simultaneity and thereby also that of distant force in the sense of Newton. It has shown how the law of motion must be modified in dealing with motions that are not negligibly small as compared with the velocity of light. It has led to a formal clarification of Maxwell's equations of the electromagnetic field; in particular it has led to an understanding of the essential oneness of the electric and the magnetic field. It has unified the laws of conservation of impulse and of energy into one single law and has demonstrated the equivalence of mass and energy. From a formal point of view one may characterize the achievement of the special theory of relativity thus: it has shown generally the role which the universal constant c (velocity of light) plays in the laws of nature and has demonstrated that there exists a close connection between the form in which time on the one hand and the spatial coordinates on the other hand enter into the laws of nature.

B. General theory of relativity.

The special theory of relativity retained the basis of classical mechanics in one fundamental point, namely the statement: The laws of nature are valid only with respect to inertial systems. The "permissible" transformations for the coordinates (i.e., those which leave the form of the laws unchanged) are exclusively the (linear) Lorentz-transformations. Is this restriction really founded in physical facts? The following argument convincingly denies ~~this~~ it.

Principle of equivalence. A body has an inertial mass (resistance to acceleration) and a heavy mass (which determines the weight of the body

in a given gravitational field, e.g., that at the surface of the earth). These two quantities, so different according to their definition, are according to experience measured by one and the same number. There must be a deeper reason for this. The fact can also be described thus: In a gravitational field different masses receive the same acceleration. Finally, it can also be expressed thus: Bodies in a gravitational field behave as in the absence of a gravitational field if, in the latter case, the system of reference used is a uniformly accelerated coordinate system (instead of an inertial system).

There seems, therefore, to be no reason to ban the following interpretation of the latter case. One considers the system as being "at rest" and considers the "apparent" gravitational field which exists with respect to it as a "real" one. This gravitational field "generated" by the acceleration of the coordinate system would of course be of unlimited extent in such a way that it could not be caused by gravitational masses in a finite region; however, if we are looking for a field-like theory, this fact need not deter us. With this interpretation the inertial system loses its meaning and one has an "explanation" for the equality of heavy and inertial mass (the same property of matter appears as weight or as inertia depending on the mode of description).

Considered formally, the admission of a coordinate system which is accelerated with respect to the inertial origin of coordinates means the admission of non-linear coordinate transformations, hence a mighty enlargement of the idea of invariance, i.e., the principle of relativity.

First, a penetrating discussion, using the results of the special theory of relativity, shows that with such a generalization the coordinates

can no longer be interpreted directly as the results of measurings. Only the coordinate difference together with the field quantities which describe the gravitational field determine measurable distances between events. After one has found oneself forced to admit non-linear coordinate transformations as transformations between equivalent coordinate systems, the simplest demand appears to admit all continuous coordinate transformations (which form a group), i.e., to admit arbitrary curvilinear coordinate systems in which the fields are described by regular functions (general principle of relativity).

Now it is not difficult to understand why the general principle of relativity (on the basis of the equivalence principle) has led to a theory of gravitation. There is a special kind of space whose physical structure (field) we can presume as precisely known on the basis of the special theory of relativity. This is empty space without electromagnetic field and without matter. It is completely determined by its "metric" property: Let dx_o, dy_o, dz_o, dt_o be the coordinate differences of two infinitesimally near points (events); then

$$ds^2 = dx_o^2 + dy_o^2 + dz_o^2 - c^2dt_o^2 \tag{1}$$

is a measurable quantity which is independent of the special choice of the inertial system. If one introduces in this space the new coordinates x_1, x_2, x_3, x_4 through a general transformation of coordinates, then the quantity ds^2 for the same pair of points has an expression of the form

$$ds^2 = \sum g_{ik}dx^i dx^k \quad \text{(summed for i and k from 1 to 4)} \tag{2}$$

where $g_{ik} = g_{ki}$. The g_{ik} which form a "symmetric tensor" and are continuous functions of x_1, ..., x_4 then describe according to the "principle of equivalence" a gravitational field of a special kind (namely one which can be retransformed to the form (1)). From Riemann's investigations on metric spaces

the mathematical properties of this g_{ik} field can be given exactly ("Riemann-condition"). However, what we are looking for are the equations satisfied by "general" gravitational fields. It is natural to assume that they too can be described as tensor-fields of the type g_{ik}, which in general do not admit a transformation to the form (1), i.e., which do not satisfy the "Riemann condition", but weaker conditions, which, just as the Riemann condition, are independent of the choice of coordinates (i.e., are generally invariant). A simple formal consideration leads to weaker conditions which are closely connected with the Riemann condition. These conditions are the very equations of the pure gravitational field (on the outside of matter and at the absence of an electromagnetic field).

These equations yield Newton's equations of gravitational mechanics as an approximate law and in addition certain small effects which have been confirmed by observation (deflection of light by the gravitational field of a star, influence of the gravitational potential on the frequency of emitted light, slow rotation of the elliptic circuits of planets -- perihelian motion of the planet Mercury). They further yield an explanation for the expanding motion of galactic systems, which is manifested by the red-shift of the light emitted from these systems.

The general theory of relativity is as yet incomplete insofar as it has been able to apply the general principle of relativity satisfactorily only to gravitational fields, but not to the total field. We do not yet know, with certainty, by what mathematical mechanism the total field in space is to be described and what the general invariant laws are to which this total field is subject. One thing, however, seems certain: namely, that the general principle of relativity will prove a necessary and effective tool for the solution of the problem of the total field.

FRANKLIN J. MEINE
1422 NORTH LA SALLE STREET
CHICAGO, ILLINOIS 60610

1947

Original Typed Article
as sent in by A. E.

FRANKLIN J. MEINE
1422 NORTH LA SALLE STREET
CHICAGO, ILLINOIS 60610

Original Galley Proofs
with some changes by
A. E. in pencil + alterations
by him.

J Meine

Hofmann & Freeman, Cambridge, Mass
apr. 1971

201 (CRAIK, Mrs. Dinah Maria Mulock, 1826-1887, authoress). A. MS. of her poem, "At a Tabernacle," corrected and revised. Octavo, two pages, mounted on an album-leaf. Eight stanzas of eight lines each, n. p., n. d.
$85.00

"THE ESSENCE OF RELATIVITY"

202 EINSTEIN, Albert (1879-1955, physicist). Original typescript, galley-proofs, and correspondence relating to his article, "The Essence of the Theory of Relativity," prepared for Nelson's Encyclopedia. Quarto and galley-octavo, thirty pages, Chicago and Princeton, New Jersey, 1946-1948.
$2000.00

A significant group of papers. On 30 September Walter Dill Scott writes (carbon copy) to Einstein asking him to contribute "an article, between 750 and 1200 words, on the Theory of Relativity--the honorarium being five hundred dollars" for a new edition of Nelson's Encyclopedia. He explains that "Our cardinal objective is to provide for the layman a truly useful, readable, accurate, and concise encyclopedia," and to this end "we have already the cooperation of approximately 115 outstanding internationally-known scientists, including such Nobel Laureates as Robert A. Millikan, Arthur H. Compton, James Franck, George R. Minot, and others." One 13 November Scott wrote again (carbon) for Einstein had not replied. Evidently Einstein then assented through his secretary, Helen Dukas, for Scott acknowledges her letter on 23 December. No later than 8 January 1947, Einstein writes to Dr. Scott (T.L.S., one page, quarto), enclosing the article itself. He asks that his fee be divided between himself ($400) and his assistant, Ernst G. Straus ($100) who "has made the English translation from the original German text." "I have to apologize for the fact that the article is somewhat longer as you have requested (sic)," he concludes, "but I found it absolutely impossible to give a clear idea of the matter in a shorter time and in a simple language." F.J. Meine, the editor-in-chief of the project, thanks Einstein (carbon) on 13 January. Galleys are now exchanged (see below) and by 1 July 1948 Meine has received "your finally approved galleys"; he submits three alternative ways of expressing the relationship between atoms, galaxies of stars, and relativity. Einstein strongly objects (T.L.S., one page, quarto, 4 July 1948) to the statement that relativity is "vital to an understanding of tiny atoms and their nuclei, &c." "for the reason that the contribution of the theory of relativity to the theory of atoms has been very modest hitherto. If you like to write something of this kind I should suggest f.i. 'has given a deeper understanding of space, time, energy and gravitation.'"

The original typescript (8 pages, quarto, about 2000 words) is present, with some half-dozen minor pen-corrections. There are three sets of galleys, the first bearing publishers' corrections, the second with at least four changes (eight words) by Einstein, and two pages of typed revision of a difficult paragraph, and the last with just one ink-correction by Einstein, but a crucial one--the insertion of a "not" in the penultimate sentence. In that instance, moreover, the original MS was considerably altered, and the negative is missing in the type-script-correction. Meine promises (1 July, above) to incorporate the change in page-proof.

203 EINSTEIN, Albert. T.L.S., one half page, quarto, to F.J. Meine (see above) regarding a proposal that he write an account of Unified Field Theory for The American People's Encylcopedia. Princeton, New Jersey, 13 March 1951.
$250.00

"THE ESSENCE OF RELATIVITY"

EINSTEIN, Albert (1879-1955, physicist). Original typescript, galley-proofs, and correspondence relating to his article, "The Essence of the Theory of Relativity," prepared for Nelson's Encyclopedia. Quarto and galley-octavo, thirty pages, Chicago and Princeton, New Jersey, 1946-1948.

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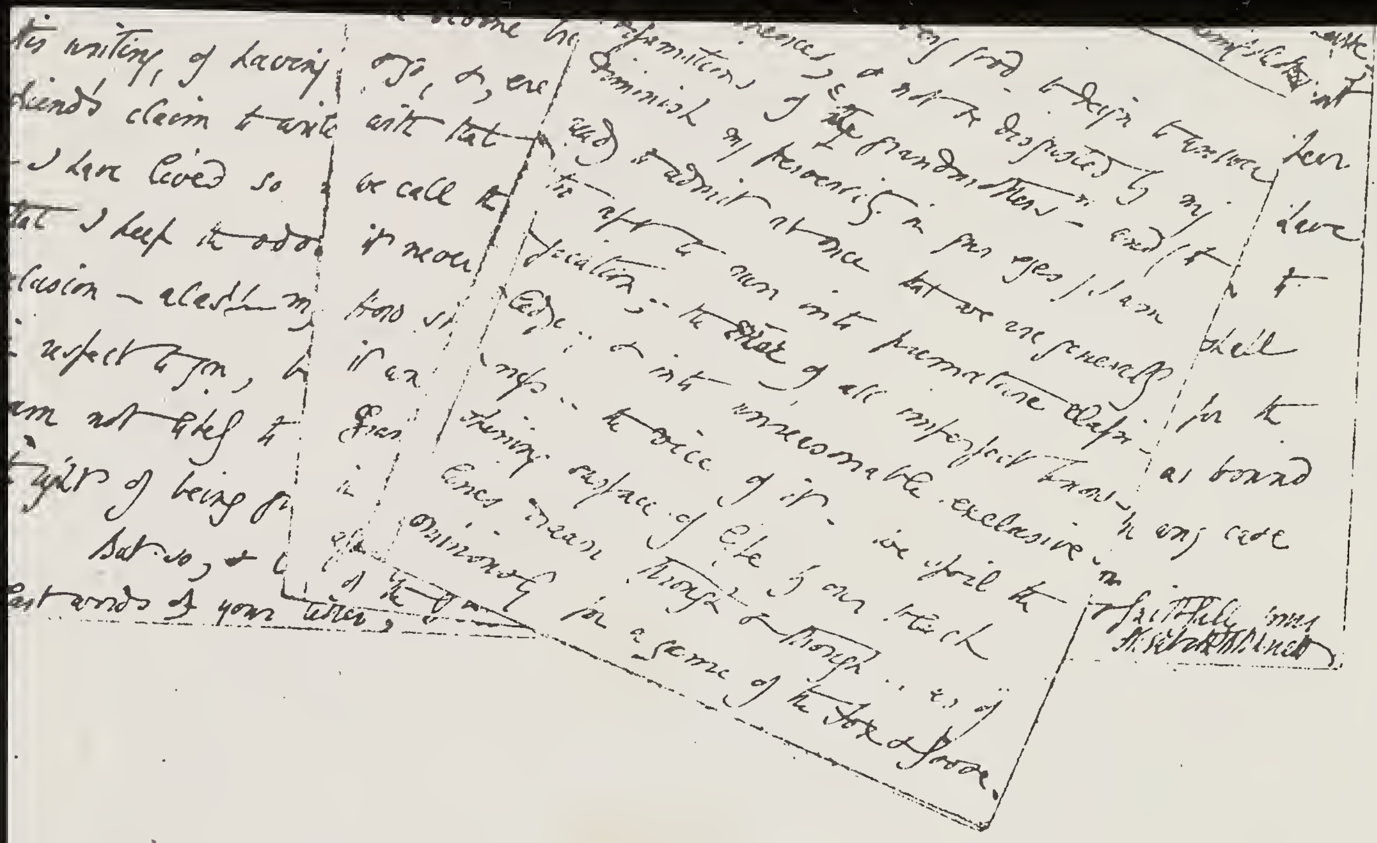
Hofmann & Freeman - 71



A MAGNIFICENT LETTER

BROWNING, Elizabeth Barrett (1806-1861, poet). Splendid, extremely long A. L. S. (Elizabeth B. Barrett) to Henry F. Chorley, litterateur. Duodecimo, eleven pages on three sheets. London, 50 Wimpole Street, 7 January 1845.

$1750.00

One of the finest literary letters of Elizabeth Barrett Browning extant, discussing in exuberant detail poetry and poets, the inferiority of female to male writers, female writers (Mrs. Hemans, Letitia Landon, Ann Bradstreet, George Sand) in particular, and her own work. Chorley was the biographer of Mrs. Hemans, and, ironically, "feminist" to EBB's "submissive" objectivity.

There is no need to quote from this rich text: it is published in full, with reasonable accuracy (saving punctuation) in the 1898 Letters, I, 230-233, when it was in the possession of R. Barrett Browning--although there "sweet mistress Anne" is erroneously glossed as "Anne (sic) Seward," not Anne Bradstreet. Cf. G. B. Taplin, The Life of Elizabeth Barrett Browning (New Haven, 1957), p. 96 and passim, and D. N. B.

September 30, 1946

Professor Albert Einstein
112 Mercer Street
Princeton, New Jersey

Dear Professor Einstein:

It is with pleasure that I ask your cooperation in a worthwhile educational project. Consolidated Book Publishers are engaged in an extensive revision of the Nelson's Encyclopedia, a forthcoming twenty volume general reference work. Our cardinal objective is to provide for the layman a truly useful, readable, accurate, and concise encyclopedia. To achieve this end we have already the cooperation of approximately 115 outstanding internationally-known scientists, including such Nobel Laureates as Robert A. Millikan, Arthur H. Compton, James Franck, George R. Minot, and others.

Your distinguished work in physics encourages us to seek your cooperation. We would be pleased if you would consider writing for us an article, between 750 and 1200 words, on the Theory of Relativity -- the honorarium being five hundred dollars ($500.00). Such an article will constitute one of our major topics, and for the layman will provide an introduction to a topic of tremendous significance.

I can assure you that no undue or undesirable publicity will be given your name in any way. We are interested in establishing a sound, scholarly list of contributors whose work and interest will make Nelson's one of the outstanding encyclopedias.

Trusting that I may have the pleasure of hearing from you about this matter, I remain

Sincerely yours,

Walter Dill Scott

WS:jmb

November 13, 1946

Professor Albert Einstein
112 Mercer Street
Princeton, New Jersey

Dear Professor Einstein:

I would be pleased to learn your decision in regard to my letter of September 30. In the event you did not receive the original letter, a copy is enclosed herewith. I sincerely hope that you will be in a position to cooperate with us on this worthwhile project.

Sincerely yours,

Walter Dill Scott

WDS:Vg
Enc.

COPY September 30, 1946

Professor Albert Einstein
112 Mercer Street
Princeton, New Jersey

Dear Professor Einstein:

It is with pleasure that I ask your cooperation in a worthwhile educational project. Consolidated Book Publishers are engaged in an extensive revision of the Nelson's Encyclopedia, a forthcoming twenty volume general reference work. Our cardinal objective is to provide for the layman a truly useful, readable, accurate, and concise encyclopedia. To achieve this end we have already the cooperation of approximately 115 outstanding internationally-known scientists, including such Nobel Laureates as Robert A. Millikan, Arthur H. Compton, James Franck, George R. Minot, and others.

Your distingusihed wo5k

December 23, 1946

Miss Helen Dukas
112 Mercer Street
Princeton, New Jersey

Dear Miss Dukas:

Please convey to Professor Einstein my appreciation for his willingness to cooperate with us by writing an article on the Theory of Relativity for the Nelson's Encyclopedia.

Very truly yours,

Walter Dill Scott

WDS:VG

January 13, 1947

Dr. Albert Einstein
112 Mercer Street
Princeton, New Jersey

Dear Dr. Einstein:

Thank you for your kind letter of January 8, and your manuscript on Relativity. Payment will be made as you requested: four hundred dollars ($400) to you; one hundred dollars ($100) to Mr. Ernst G. Straus.

Our science editor has the manuscript, and will communicate with you in the very near future.

Sincerely yours,

Franklin J. Meine
Editor-in-Chief

FJM:VG

July 1, 1948

Dr. Albert Einstein
112 Mercer Street
Princeton, New Jersey

Dear Dr. Einstein:

We are delighted to have your finally approved galley and the correction in your most recent manuscript. Inserting the word "not" in the last paragraph will be carried out and checked in page proof.

We frequently put a special heading on some of our more important articles, such as yours, and I would like to have your approval of this heading which we would like to use:

RELATIVITY . Essence of the Theory

Vital to an understanding of tiny atoms and their nuclei, as well as of motions of vast, remote galaxies of stars

We are enclosing a page on which such a heading appears simply as an example of the way it looks.

Naturally we would not want to use any heading for your article which would not meet with your approval.

Sincerely yours,

fjm:ka

Franklin J. Meine
Editor-in-Chief

Relativity — Essence of the Theory

~~Vital to an understanding of tiny atoms
and their nuclei and of motions of the
vast, remote galaxies of stars~~

Mary Clapp votes for this

Vital to an understanding of tiny atoms
and their nuclei, as well as of motions
of vast, remote galaxies of stars

Mr. Weiner votes for this

A revolutionary advance in fundamental
physical theory with vital applications to
remote galaxies and to interiors of atoms

2

July 4,1948

Discussion with me regarding article FJMeine

Mr.Franklin J.Meine
Editor-in-Chief
American People's Encyclopedia
154 No.Michigan Ave.
Chicago,Ill.

My dear Mr.Meine:

The remark you proposed "vital to an understanding of tiny atoms and their nuclei,as well as of motions of vast,remote galaxies of stars" seems to me not acceptable for the reason that the contribution of the theory of relativity to the theory of atoms has been very modest hitherto. If you like to write something of this kind I should suggest f.i. "has given a deeper understanding of space,time, energy and gravitation".

Sincerely yours,

A. Einstein.

Albert Einstein.

History. Joseph Monier, a Parisian gardener, is often credited with the introduction of reinforced concrete, but the idea of using steel and iron to supplement the strength of concrete was not the product of a single mind. Scores of engineers and craftsmen took part in the early experiments and later developments.

The first experiment of which there is a complete record was conducted by Sir Marc Isambard Brunel in London, England, in 1832. Brunel was building a tunnel under the Thames River and built an experimental arch of brick and cement, using strips of hoop-iron and wood for reinforcement. All early development work was done in Europe and Great Britain. The use of reinforced concrete for walls, roofs, beams, and arches had progressed far before much attention was paid to its use in America. Monier, perhaps the best known of the early experimenters, received a patent in 1867 on a method of reinforcing concrete with iron wire mesh. Other inventors patented various methods.

In the United States, among the earliest examples of experimental construction with reinforced concrete is a house in Port Chester, N.Y., built by W. E. Ward in 1871 and 1872. Interior and exterior walls, floors, and roof were built of concrete, the bottom of the beams being reinforced with light I beams. The first reinforced concrete bridge in the United States is believed to have been a small one built in Prospect Park in Brooklyn in 1871.

Developments and Applications. The first important practical applications of reinforced concrete for building construction were promoted on the Pacific coast by E. L. Ransome, beginning about 1874. He first used old wire cable and hoop-iron for reinforcement. In 1884 he took out a patent on a deformed bar, made by twisting a square bar. He built the famous Leland Stanford, Jr. Museum at Palo Alto, which came through the 1906 earthquake with minor damage. An addition to the borax works at Alameda, Calif., which Ransome built in 1889, is said to be the first example of ribbed floor construction in America.

Joseph Melan, an Austrian, was the inventor of a system of reinforcing concrete with specially designed structural shapes; his system was introduced into the United States by an Austrian associate, Fritz Emperger, about 1893. A paper describing the Melan system, delivered by Emperger before the American Society of Civil Engineers in 1894, is said to be the first detailed technical description of the use of reinforced concrete for bridges ever given in this country.

One of the most notable of all reinforced concrete bridges is the Tunkhannock Viaduct, among the largest concrete bridges in the world. It is 2,375 feet long, rises 300 feet above its foundations, bedded in solid rock, and required 165,000 cubic yards of concrete. This bridge was built in 1912–1914.

Other notable reinforced concrete bridges in the United States include the Capplen Memorial Arch Bridge at Minneapolis; the Bay Bridge at San Francisco; the Lake Pontchartrain Bridge in Louisiana; the James River Bridge at Newport News, the Two Mile Viaduct at Long Key, Fla., and the Lake Washington Pontoon Bridge at Seattle, Wash. The five-span George Westinghouse Bridge at East Pittsburgh, Pa., has one of the longest concrete arches in the country, 460 feet with a rise of 156 feet. But increase in the number and size of American bridges is not the most important contribution to bridgebuilding resulting from the development of reinforced concrete. Equally important has been improvement in the architectural design of bridges, made possible by the use of concrete that can be made to assume any intricate shape, form, or texture conceived by the designer. Improvement in the architectural appearance of bridges has been most notable during the past 25 years.

The first skyscraper type reinforced concrete building to be erected in the United States was the 16-story Ingalls Building in Cincinnati, Ohio, designed by William P. Anderson and completed in 1903. Original plans for the building had called for structural steel construction, but slow deliveries of steel led to acceptance of Anderson's proposal to use reinforced concrete. Since that time thousands of large reinforced concrete buildings have been constructed in every part of the country, including some of the largest schools, hospitals, hotels, public buildings, office buildings, and factories in the world. A number of the great dams such as Hoover Dam and Grand Coulee Dam are of reinforced concrete.

Herbert C. Person

Bibliog.–H. Sutherland and R. C. Reese, *Introduction to Reinforced Concrete Design* (1943); G. A. Hool and W. S. Kinne, *Reinforced Concrete and Masonry Structures* (1944); W. S. Gray, *Reinforced Concrete Water Towers, Bunkers, Silos, and Gantries* (1944); C. W. Dunham, *Theory and Practice of Reinforced Concrete* (1944).

REINHARDT, MAX, real name **Max Goldmann,** 1873–1943, Austrian theatrical producer, was born in Baden. Beginning as a character actor, he became manager of the Kleine Theater's cabaret *Schall und Rauch* and director of the Neues Theater by 1902. In 1905, as director of the Kammerspiele and the Deutsches Theater, he began to make stage history with his impressionistic productions of Shakespeare, Molière, Gorki, Wilde, Strindberg, Wedekind, and Shaw. In the summer he managed the Salzburg Festspielhaus, producing each season the old mystery play, *Everyman*. His production of Karl Vollmöller's pantomime, *The Miracle*, in 1912 established his reputation internationally; and when the Nazis forced him to leave Germany in 1932, he went to London to stage *A Midsummer Night's Dream* for the Oxford University Dramatic Society. Two years later he went to America to supervise the film version of *A Midsummer Night's Dream* and in 1937 he produced Franz Werfel's *The Eternal Road* in New York.

REJECTION, PARENTAL. See Parenthood.

RELATIVE HUMIDITY, PERCENTAGE OF, a term indicating the moisture content of any atmosphere per unit weight as compared to the total amount that could be contained by the atmosphere at its particular temperature. Saturation at any temperature is given as 100 per cent. In contrast, *absolute humidity* indicates the moisture content in grains of moisture per cubic foot of dry air. See Air Conditioning; Heating and Ventilation; Humidity; Psychrometry.

RELATIVITY. The Essence of the Theory of Relativity. Mathematics deals exclusively with the relations of concepts to each other without consideration of their relation to experience. Physics, too, deals with mathematical concepts; however, these concepts attain physical content only by the clear determination of their relation to the objects of experience. This in particular is the case for the concepts of motion, space, time.

The theory of relativity is that physical theory which is based on a consistent physical interpretation of these three concepts. The name "theory of relativity" is connected with the fact that motion, from the point of view of possible experience, always appears as the *relative* motion of one object with respect to another (e.g., of a car with respect to the ground, or the earth with respect to the sun and the fixed stars). Motion is never observable as "motion with respect to space" or, as it has been expressed, as "absolute motion." The "principle of relativity" in its widest sense is contained in the statement: The totality of physical phenomena is of such a character that it gives no basis for the introduction of the concept of "absolute motion"; or, shorter but less precise: There is no absolute motion.

It might seem that our insight would gain little from such a negative statement. In reality, however, it is a strong restriction for the (conceivable) laws of nature. In this sense there exists an analogy between the theory of relativity and thermodynamics. The latter, too, is based on a negative statement: "There exists no perpetuum mobile."

The development of the theory of relativity proceeded in two steps, "special theory of relativity" and "general theory of relativity." The latter presumes the validity of the former as a limiting case and is its consistent continuation.

Special Theory of Relativity

Physical Interpretation of Space and Time in Classical Mechanics. Geometry, from a physical standpoint, is the totality of laws according to which rigid bodies mutually at rest can be placed with respect to each other (e.g., a triangle consists of three rods whose ends touch permanently). It is assumed that with such an interpretation the Euclidean laws are valid. "Space" in this interpretation is in principle an infinite rigid body (or skeleton) to which the position of all other bodies is related (body of reference). Analytic geometry (Descartes) uses as the body of reference, which represents space, three mutually perpendicular rigid rods on which the "co-ordinates" (x, y, z) of space points are measured in the known manner as perpendicular projections (with the aid of a rigid unit-measure).

Simultaneity. Physics deals with "events" in space and time. To each event belongs, besides its place co-ordinates x, y, z, a time value t. The latter was considered measurable by a clock (ideal periodic process) of negligible spatial extent. This clock C is to be considered at rest at one point of the co-ordinate system, e.g., at the co-ordinate origin $(x=y=z=0)$. The time of an event taking place at a point P(x, y, z) is then defined as the time shown on the clock C simultaneously with the event. Here the concept "simultaneous" was assumed as physically meaningful without special definition. This is a lack of exactness which seems harmless only since, with the help of light (whose velocity is practically infinite from the point of view of daily experience), the simultaneity of spatially distant events can apparently be decided immediately.

The special theory of relativity removes this lack of precision by defining simultaneity physically with the use of light signals. The time t of the event in P is the reading of the clock C at the time of arrival of a light signal emitted from the event, corrected with respect to the time needed for the light signal to travel the distance. This correction presumes (postulates) that the velocity of light is constant.

This definition reduces the concept of simultaneity of spatially distant events to that of the simultaneity of events happening at the same place (coincidence), namely the arrival of the light signal at C and the reading of C.

Inertial Systems and the L-Principle. Classical mechanics is based on Galileo's principle: A body is in rectilinear and uniform motion as long as other bodies do not act on it. This statement cannot be valid for arbitrary moving systems of co-ordinates. It can claim validity only for so-called "inertial systems." Inertial systems are in rectilinear and uniform motion with respect to each other. In classical physics laws claim validity only with respect to all inertial systems (special principle of relativity).

It is now easy to understand the dilemma which has led to the special theory of relativity. Experience and theory have gradually led to the conviction that light in empty space always travels with the same velocity c independent of its color and the state of motion of the source of light (principle of the constancy of the velocity of light—in the following referred to as "L-principle"). Now elementary intuitive considerations seem to show that the same light ray *cannot* move with respect to all inertial systems with the same velocity c. The L-principle seems to contradict the special principle of relativity.

It turns out, however, that this contradiction is only an apparent one which is based essentially on the prejudice about the absolute character of time or, rather, of the simultaneity of distant events. We just saw that x, y, z and t of an event can, for the moment, be defined only with respect to a certain chosen system of co-ordinates (inertial system). The transformation of the x, y, z, t of events which has to be carried out with the passage from one inertial system to another (co-ordinate transformation), is a problem which cannot be solved without special physical assumptions. However, the following postulate is exactly sufficient for a solution: *The L-principle holds for all inertial systems* (application of the special principle of relativity to the L-principle). The transformations thus defined, which are linear in x, y, z, t, are called Lorentz transformations. Lorentz transformations are formally characterized by the demand that the expression

$$dx^2+dy^2+dz^2-c^2dt^2,$$

which is formed from the co-ordinate-differences dx, dy, dz, dt of two infinitely close events, be invariant (i.e., that through the transformation it goes over into the *same* expression formed from the co-ordinate differences in the new system).

With the help of the Lorentz transformations the special principle of relativity can be expressed thus: The laws of nature are invariant with respect to Lorentz-transformations (i.e., a law of nature does not change its form if one introduces into it a new inertial system with the help of a Lorentz-transformation on x, y, z, t).

Results of the Special Theory of Relativity. The special theory of relativity has led to a clear understanding of the physical concepts of space and time and in connection with this to a recognition of the behavior of moving measuring rods and clocks. It has in principle removed the concept of absolute simultaneity and thereby also that of instantaneous action at a distance in the sense of Newton. It has shown how the law of motion must be modified in dealing with motions that are not negligibly small as compared with velocity of light. It has led to a formal clarification of Maxwell's equations of the electromagnetic field; in particular it has led to an understanding of the essential oneness of the electric and the magnetic field. It has unified the laws of conservation of momentum and of energy into one single law and has demonstrated the equivalence of mass and energy. From a formal point of view one may characterize the achievement of the special theory of relativity thus: it has shown generally the role which the universal constant c (velocity of light) plays in the laws of nature and has demonstrated that there exists a close connection between the form in which time on the one hand and the spatial co-ordinates on the other hand enter into the laws of nature.

General Theory of Relativity

The special theory of relativity retained the basis of classical mechanics in one fundamental point, namely the statement: The laws of nature are valid only with respect to inertial systems. The "permissible" transformations for the co-ordinates (i.e., those which leave the form of the laws unchanged) are *exclusively* the (linear) Lorentz-transformations. Is this restriction really founded in physical facts? The following argument convincingly denies it.

Principle of Equivalence. A body has an inertial mass (resistance to acceleration) and a heavy mass (which determines the weight of the body in a given gravitational field, e.g., that at the surface of the earth). These two quantities, so different according to their definition, are according to experience measured by one and the same number. There must be a deeper reason for this. The fact can also be described thus: In a gravitational field different masses receive the same acceleration. Finally, it can also be expressed thus: Bodies in a gravitational field behave as in the absence of a gravitational field if, in the latter case, the system of reference used is a uniformly accelerated co-ordinate system (instead of an inertial system).

There seems, therefore, to be no reason to ban the following interpretation of the latter case. One considers the system as being "at rest" and considers the "apparent" gravitational field which exists with respect to it as a "real" one. This gravitational field "generated" by the acceleration of the co-ordinate system would of course be of unlimited extent in such a way that it could not be caused by gravitational masses in a finite region; however, if we are looking for a fieldlike theory, this fact need not deter us. With this interpretation the inertial system loses its meaning and one has an "explanation" for the equality of heavy and inertial mass (the same property of matter appears as weight or as inertia depending on the mode of description).

Considered formally, the admission of a co-ordinate system which is accelerated with respect to the original "inertial" co-ordinates means the admission of nonlinear co-ordinate transformations, hence a mighty enlargement of the idea of invariance, i.e., the principle of relativity.

First, a penetrating discussion, using the results of the special theory of relativity, shows that with such a generalization the co-ordinates can no longer be interpreted directly as the results of measurements. Only the co-ordinate difference together with the field quantities which describe the gravitational field determine measurable distances between events. After one has found oneself forced to admit nonlinear co-ordinate transformations as transformations between equivalent co-ordinate systems, the simplest demand appears to admit all continuous co-ordinate transformations (which form a group), i.e., to admit arbitrary curvilinear co-ordinate systems in which the fields are described by regular functions (general principle of relativity).

Finally approved galley,
as per letter by Mr.
Franklin J. Meine
July 1, 1948

GAL. R-86-B — — — —

Gravitation in the General Theory of Relativity. Now it is not difficult to understand why the general principle of relativity (*on the basis of the equivalence principle*) has led to a theory of gravitation. There is a special kind of space whose physical structure (field) we can presume as precisely known on the basis of the special theory of relativity. This is empty space without electromagnetic field and without matter. It is completely determined by its "metric" property: Let dx_0, dy_0, dz_0, dt_0 be the co-ordinate differences of two infinitesimally near points (events); then

$$(1)\ ds^2 = dx_0^2 + dy_0^2 + dz_0^2 - c^2dt_0^2$$

is a measurable quantity which is independent of the special choice of the inertial system. If one introduces in this space the new co-ordinates x_1, x_2, x_3, x_4 through a general transformation of co-ordinates, then the quantity ds^2 for the same pair of points has an expression of the form

$$(2)\ ds^2 = \Sigma g_{ik}dx^i dx^k$$

(summed for i and k from 1 to 4) where $g_{ik} = g_{ki}$. The g_{ik} which form a "symmetric tensor" and are continuous functions of $x_1, \ldots, x_4$ then describe according to the "principle of equivalence" a gravitational field of a special kind (namely one which can be retransformed to the form (1)). From Riemann's investigations on metric spaces the mathematical properties of this g_{ik} field can be given exactly ("Riemann-condition"). However, what we are looking for are the equations satisfied by "general" gravitational fields. It is natural to assume that they, too, can be described as tensor-fields of the type g_{ik}, which in general do *not* admit a transformation to the form (1), i.e., which do not satisfy the "Riemann condition," but weaker conditions, which, just as the Riemann condition, are independent of the choice of co-ordinates (i.e., are generally invariant). A simple formal consideration leads to weaker conditions which are closely connected with the Riemann condition. These conditions are the very equations of the pure gravitational field (on the outside of matter and at the absence of an electromagnetic field).

Experimental Verifications of the General Theory of Relativity. These equations yield Newton's equations of gravitational mechanics as an approximate law and in addition certain small effects which have been confirmed by observation (deflection of light by the gravitational field of a star, influence of the gravitational potential on the frequency of emitted light, slow rotation of the elliptic circuits of planets—perihelian motion of the planet Mercury). They further yield an explanation for the expanding motion of galactic systems, which is manifested by the red-shift of the light emitted from these systems.

The general theory of relativity is as yet incomplete insofar as while it leads to a well-defined theory of the
not
gravitational field it does determine sufficiently the theory of the total field (which includes the electromagnetic field). The reason for this is the fact that the general field laws are not sufficiently determined by the general principle of relativity *alone*.

ALBERT EINSTEIN

E. WEIL 28, LITCHFIELD WAY, LONDON, N.W.11

February 22nd,1947

Dear Mr.Dibner,

I have just acquired an Einstein autograph Ms. of unusual interest and thought I would let you know first of all.

It is the original MS in Einstein's hand,with numerous corrections (and even two ink-stains) on six numbered folio leaves to the item 149 of my Einstein bibliography (copy enclosed) which was published at Berlin in 1925. Although autographs of Einstein are not rare,a complete MS dealing with the theory of relativity is certainly uncommon.

Although it starts:"Herr Eddington und Herr Courant haben mich aufgefordert.." it is not signed at the end. But I believe it would not be difficult for you to get Einstein to sign this authentic MS if he hears that it will be incorporated in your collection.

As it is,I have priced the MS. with $ 180.- and if you would be interested to see it,before deciding upon its acquisition,I will gladly send it to you for your inspection. I will not show it to any-body until I have heard from you and I remain,dear Mr.Dibner,

Yours sincerely

E.Weil

E. WEIL 28, LITCHFIELD WAY, LONDON, N.W.11

Albert Einstein. A Bibliography of his Scientific Papers 1901-1930.

No.149. 1925 Eddingtons Theorie und Hamiltonsches Prinzip. "Anhang" to "Relativitaetstheorie in mathematischer Behandlung", by A.S.Eddington, Cambridge. Authorised translation by Ostrowski and Harry Scmidt. Berlin, J.Springer, 1925.

Anhang

Eddingtons Theorie und Hamilton'sches Prinzip.

Herr Eddington und ~~der deutsche Herausgeber Prof.~~ Herr Courant haben mich aufgefordert, der deutschen Übersetzung dieses Werkes einen kleinen Anhang beizufügen über die Anwendbarkeit des Hamilton'schen Prinzipes in der Eddington'schen Theorie. Ich komme dieser Aufforderung gerne nach, wenn ich auch zugunsten des hier Vorzubringenden nicht viel mehr anführen kann, als dass es sich um eine im Rahmen des Weyl-Eddington'schen ~~Systemes~~ Gedankenganges natürliche ~~Gedankengang~~ Betrachtung handelt.

Wir gehen ~~von~~ aus Eddingtons Grundgedanken, alle ~~Begriffe~~ Grössen der Feldtheorie sowie deren naturgesetzliche Zusammenhänge auf das Gesetz des affinen Zusammenhanges, d. h. auf die in (92,1) definierten $\Gamma^{\sigma}_{\mu\nu}$ zurückzuführen. ~~dann als Ausgangs~~ In §92 ist ~~schon~~ gezeigt, dass es ein invariantes Integral gibt, dessen Integrand eine Tensordichte $\mathfrak{H}$ ist, die nur von den $\Gamma^{\sigma}_{\mu\nu}$ und den ersten Differentialquotienten dieser Grössen abhängt ~~abhängt~~. Es liegt daher nahe, zu versuchen, die Feldgesetze aus einem Variationsprinzip abzuleiten, in welchem ein derartiges Integral nach den $\Gamma^{\sigma}_{\mu\nu}$ als unabhängigen Variabeln variiert wird. Bei der Durchführung dieses Gedankens wird man dazu geführt, den Zusammenhang zwischen den $\Gamma^{\sigma}_{\mu\nu}$ und dem durch die zu beschreibenden metrischen Felde etwas anders zu formulieren als dies Eddington gethan hat.

Es sei $\mathfrak{H}$ eine Tensordichte, welche nur von den Grössen $\Gamma^{\sigma}_{\mu\nu}$ und deren ersten Differentialquotienten abhängt. Es sei ferner für jede am Rande eines ins Auge gefassten Integrationsgebietes verschwindende Variation der $\Gamma^{\sigma}_{\mu\nu}$

$$\delta\left\{\int \mathfrak{H}\, d\tau\right\} = 0, \quad \ldots \quad (1)$$

wobei $d\tau = dx_1\, dx_2\, dx_3\, dx_4$ gesetzt ist.

Bevor wir aus diesem ~~Grund~~ Axiom Folgerungen ziehen, wollen wir eine logisch willkürliche Beschränkung einführen. Die ~~Invariante~~ skalare Dichte $\mathfrak{H}$ soll nicht in der denkbar allgemeinsten Weise von den Γ abhängen, d. h. nicht in beliebiger Weise aus den ${}^*B^{\xi}_{\mu\nu\sigma}$ (92,41) gebildet sein, sondern ausschliesslich

aus deren Verjüngung $^*G_{\mu\nu}$ (92,42), beziehungsweise aus dem symmetrischen und dem antisymmetrischen Bestandteil dieses Tensors:

$$\gamma_{\mu\nu} = -\frac{\partial \Gamma^{\alpha}_{\mu\nu}}{\partial x_\alpha} + \Gamma^{\alpha}_{\mu\beta}\Gamma^{\beta}_{\nu\alpha} + \frac{1}{2}\left(\frac{\partial \Gamma^{\alpha}_{\mu\alpha}}{\partial x_\nu} + \frac{\partial \Gamma^{\alpha}_{\nu\alpha}}{\partial x_\mu}\right) - \Gamma^{\alpha}_{\mu\nu}\Gamma^{\beta}_{\alpha\beta} \quad \ldots (2)$$

$$\varphi_{\mu\nu} = \frac{1}{2}\left(\frac{\partial \Gamma^{\alpha}_{\mu\alpha}}{\partial x_\nu} - \frac{\partial \Gamma^{\alpha}_{\nu\alpha}}{\partial x_\mu}\right). \quad \ldots \quad (3)$$

Gemäss dieser Voraussetzung erhält man an Stelle von (1) zunächst

$$\int(\mathfrak{g}^{\mu\nu}\delta\gamma_{\mu\nu} + \mathfrak{f}^{\mu\nu}\delta\varphi_{\mu\nu})\,d\tau = 0, \quad \ldots\ldots (1a)$$

wobei gesetzt ist

$$\left.\begin{aligned} \frac{\partial \mathfrak{H}}{\partial \gamma_{\mu\nu}} &= \mathfrak{g}^{\mu\nu} \\ \frac{\partial \mathfrak{H}}{\partial \varphi_{\mu\nu}} &= \mathfrak{f}^{\mu\nu}. \end{aligned}\right\} \quad \ldots (4)$$

In (1a) sind $\delta\gamma_{\mu\nu}$ und $\delta\varphi_{\mu\nu}$ vermöge (2) und (3) durch die $\Gamma^{\sigma}_{\mu\nu}$ und $\delta\Gamma^{\sigma}_{\mu\nu}$ auszudrücken. Mit Rücksicht darauf, dass die 40 Variationen $\delta\Gamma^{\sigma}_{\mu\nu}$ von einander unabhängig wählbar sind, erhält man aus (1a) vierzig Gleichungen:

$$\mathfrak{g}^{\mu\nu}{}_{;\alpha} - \frac{1}{2}\mathfrak{g}^{\mu\sigma}{}_{;\sigma}\delta^{\nu}_{\alpha} - \frac{1}{2}\mathfrak{g}^{\nu\sigma}{}_{;\sigma}\delta^{\mu}_{\alpha} - \frac{1}{2}\mathfrak{i}^{\mu}\delta^{\nu}_{\alpha} - \frac{1}{2}\mathfrak{i}^{\nu}\delta^{\mu}_{\alpha} = 0. \quad \ldots (1b)$$

Dabei sind die Tensordichten

$$\mathfrak{g}^{\mu\nu}{}_{;\alpha} = \frac{\partial \mathfrak{g}^{\mu\nu}}{\partial x_\alpha} + \mathfrak{g}^{\sigma\nu}\Gamma^{\mu}_{\sigma\alpha} + \mathfrak{g}^{\mu\sigma}\Gamma^{\nu}_{\sigma\alpha} - \mathfrak{g}^{\mu\nu}\Gamma^{\sigma}_{\alpha\sigma} \quad \ldots (5)$$

$$\mathfrak{i}^{\mu} = \frac{\partial \mathfrak{f}^{\mu\sigma}}{\partial x_\sigma} \quad \ldots\ldots (6)$$

eingeführt. Die 40 Gleichungen (1b) erlauben uns, die 40 Grössen $\Gamma^{\sigma}_{\mu\nu}$ durch die $\mathfrak{g}^{\mu\nu}$, $\mathfrak{f}^{\mu\nu}$ und deren Ableitungen auszudrücken. Um dies zu bewerkstelligen, muss man von den kontravarianten Tensordichten zu den kontravarianten Tensoren und von diesen zu den kovarianten Tensoren übergehen. Wir definieren zu diesem Zweck die Tensoren $g^{\mu\nu}$ und $g_{\mu\nu}$ durch die Gleichungen

$$\left.\begin{aligned} g^{\mu\nu}\sqrt{-g} &= \mathfrak{g}^{\mu\nu} \\ g_{\mu\sigma}g^{\nu\sigma} &= \delta^{\nu}_{\mu} \\ g &= |g_{\mu\nu}|, \end{aligned}\right\} \quad \ldots\ldots (7)$$

ferner i^μ und i_μ durch die Gleichungen

$$\left.\begin{aligned} i^\mu \sqrt{-g} &= \mathfrak{i}^\mu \\ i_\mu &= g_{\mu\nu} i^\nu \end{aligned}\right\} \cdots (8)$$

und erhalten nach elementarer Rechnung[×]

$$\Gamma^\alpha_{\mu\nu} = \frac{1}{2} g^{\alpha\beta}\left(\frac{\partial g_{\mu\beta}}{\partial x_\nu} + \frac{\partial g_{\nu\beta}}{\partial x_\mu} - \frac{\partial g_{\mu\nu}}{\partial x_\beta}\right) - \frac{1}{2} g_{\mu\nu} i^\alpha + \frac{1}{6}\delta_\mu^\alpha i_\nu + \frac{1}{6}\delta_\nu^\alpha i_\mu \ldots (1c)$$

Dies Resultat zeigt deutlich, dass man die $g_{\mu\nu}$ als metrischen Tensor aufzufassen hat. Der aus dem Variationsprinzip folgende Ausdruck für die $\Gamma^\alpha_{\mu\nu}$ hat grosse Aehnlichkeit mit dem aus der Weyl'schen Theorie folgenden; auch hier tritt neben dem metrischen Tensor ein Vierer-Vektor auf. ~~Nun man~~ Die Feldgleichungen für die $g_{\mu\nu}$ und $f^{\mu\nu}$ stecken bereits in den bisher enthaltenen Resultaten, sobald man den Ausdruck für die Hamilton'sche Funktion $\mathfrak{H}$ angenommen hat. Die Feldgleichungen entstehen nämlich aus den Gleichungen (2) und ~~der~~ (3), indem man deren rechte und linke Seite durch die $g_{\mu\nu}$ und $f^{\mu\nu}$ ausdrückt. Für die rechten Seiten leistet dies die Gleichung (1c), für die linken Seiten die Gleichungen (4). Ist nämlich $\mathfrak{H}$ als Funktion der $g_{\mu\nu}$ und $\varphi_{\mu\nu}$ gegeben, so kann man aus (4) die $\mathfrak{g}_{\mu\nu}$ und $\varphi_{\mu\nu}$ durch die $\mathfrak{g}^{\mu\nu}$ und $\mathfrak{f}^{\mu\nu}$ ausdrücken und das Ergebnis ~~auf~~ der linken Seite von (2) und (3) einsetzen.

Einfacher gelangt man – was die linke Seite von (2) und (3) anlangt – in folgender Weise zum Ziel. Da wir bisher bezüglich

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× Durch Verjüngen von (1b) nach den Indices ν, α erhält man zunächst

$$\mathfrak{g}^{\mu\sigma}{}_{;\sigma} = -\frac{5}{3}\mathfrak{i}^\mu,$$

wodurch man anstelle von (1b) hat:

$$\mathfrak{g}^{\mu\nu}{}_{;\alpha} + \frac{1}{3}\mathfrak{i}^\mu\delta_\alpha^\nu + \frac{1}{3}\mathfrak{i}^\nu\delta_\alpha^\mu = 0$$

Hierin ersetze man $\mathfrak{g}^{\mu\nu}{}_{;\alpha}$ gemäss (5). Nun kann man gemäss der ersten der Gleichungen (7) zu der kontravarianten Form übergehen ~~und hierauf durch zweimaliges~~

$$\frac{\partial g^{\mu\nu}}{\partial x_\alpha} + g^{\mu\sigma}\Gamma^\nu_{\sigma\alpha} + g^{\nu\sigma}\Gamma^\mu_{\sigma\alpha} + \frac{1}{3} i^\mu\delta_\alpha^\nu + \frac{1}{3} i^\nu\delta_\alpha^\mu + g^{\mu\nu}\left(\frac{\partial \lg\sqrt{-g}}{\partial x_\alpha} - \Gamma^\sigma_{\alpha\sigma}\right) = 0$$

Nach Multiplizieren mit $g_{\mu\nu}$ erkennt man, dass die Klammer des letzten Gliedes gleich $-\frac{1}{3} i_\alpha$ ist. ~~Nach~~ Nach Übergang zu kovarianten Indizes erhält man dann durch Auflösen nach den Γ in bekannter Weise die Gleichung (1c)

der Wahl der skalaren Dichte $\mathfrak{H}$ in Funktion der γ und φ noch keine Annahme eingeführt haben, drücken die Gleichungen (4) nichts anderes aus, als dass

$$\mathfrak{g}^{\mu\nu} d\gamma_{\mu\nu} + \mathfrak{f}^{\mu\nu} d\varphi_{\mu\nu}$$

(bezüglich der Variabeln $\gamma_{\mu\nu}$ und $\varphi_{\mu\nu}$) ein vollständiges Differential ist. Damit gleichbedeutend ist die Aussage, dass

$$\gamma_{\mu\nu} d\mathfrak{g}^{\mu\nu} + \varphi_{\mu\nu} d\mathfrak{f}^{\mu\nu}$$

ein vollständiges Differential ist. Indem wir nun umgekehrt die $\gamma_{\mu\nu}$ und $\varphi_{\mu\nu}$ als Funktionen der $\mathfrak{g}^{\mu\nu}$ und $\mathfrak{f}^{\mu\nu}$ ansehen. Unser Ergebnis bedeutet dann, dass eine Funktion $\mathfrak{H}^*$ der $\mathfrak{g}^{\mu\nu}$ und $\mathfrak{f}^{\mu\nu}$ vom Charakter einer Skalar-Dichte existiert, welche die Bedingungen

$$\left.\begin{aligned} \gamma_{\mu\nu} &= \frac{\partial \mathfrak{H}^*}{\partial \mathfrak{g}^{\mu\nu}} \\ \varphi_{\mu\nu} &= \frac{\partial \mathfrak{H}^*}{\partial \mathfrak{f}^{\mu\nu}} \end{aligned}\right\} \quad \ldots (4a)$$

erfüllt. Die Wahl der Funktion $\mathfrak{H}^*$ bestimmt die ~~linken~~ Seiten von (2) und (3) vollständig. Die Funktionen $\mathfrak{H}$ und $\mathfrak{H}^*$ bedingen einander eindeutig. Es ist nämlich

$$d\mathfrak{H} + d\mathfrak{H}^* = \gamma_{\mu\nu} \mathfrak{g}^{\mu\nu} + \varphi_{\mu\nu} \mathfrak{f}^{\mu\nu}, \quad \ldots (9)$$

oder, falls $\mathfrak{H}^*$ eine homogene quadratische Funktion der ~~g und~~ $\mathfrak{f}^{\mu\nu}$ und eine homogene Funktion nullten Grades der $\mathfrak{g}^{\mu\nu}$ ist

$$\mathfrak{H} = \mathfrak{H}^* \text{*} \quad (9a)$$

Mit Rücksicht auf die Maxwell'sche Theorie setzen wir

$$\mathfrak{H}^* = -\frac{\beta}{2} \mathfrak{f}_{\alpha\beta} \mathfrak{f}^{\alpha\beta} \sqrt{-g} = -\frac{\beta}{2} g_{\sigma\alpha} g_{\tau\beta} \mathfrak{f}^{\sigma\tau} \mathfrak{f}^{\alpha\beta} \sqrt{-g} \quad \ldots (10)$$

Hiebei ist β eine Konstante, g die Determinante $|\mathfrak{g}^{\alpha\beta}|$, $g_{\sigma\alpha}$ die normierten Unterdeterminanten zu den $\mathfrak{g}^{\sigma\alpha}$. Hieraus folgt durch einfache Rechnung

$$d\mathfrak{H}^* = -\beta \left[\left(\frac{1}{4} g_{\alpha\beta} \mathfrak{f}_{\sigma\tau} \mathfrak{f}^{\sigma\tau} - \mathfrak{f}_{\alpha\sigma} \mathfrak{f}_{\beta}{}^{\sigma} \right) \delta \mathfrak{g}^{\alpha\beta} + \mathfrak{f}_{\alpha\beta} \delta \mathfrak{f}^{\alpha\beta} \right] \quad \ldots (11)$$

* Man erkennt aus (10) und (9) leicht, dass ~~bei~~ diesem Ansatz Gleichung (9a) erfüllt ist.

oder gemäss (4a)

$$\left.\begin{aligned} \gamma_{\mu\nu} &= -\beta\left(\tfrac{1}{4}\, g_{\alpha\beta}\, f_{\sigma\tau} f^{\sigma\tau} - f_{\alpha\sigma} f_{\beta}{}^{\sigma}\right) = -\beta\, \mathfrak{E}_{\mu\nu} \\ \varphi_{\mu\nu} &= -\beta\, f_{\mu\nu} \quad \ldots\ldots \end{aligned}\right\} \quad (11a)$$

Diese Gleichungen bestimmen in Verbindung mit (2), (3) und
die Gleichungen (1c) die Feldgleichungen. $\mathfrak{E}_{\mu\nu}$ ist der elektromag-
netische Energietensor der Maxwell'schen Theorie. Es sei bemerkt, dass man
der Funktion $\mathfrak{H}$ ein Glied von der Form konst. $\sqrt{-g}$ additiv beifügen könnte,
welches dem „kosmologischen" Gliede der allgemeinen Relativitätstheorie
entsprechen würde.

Durch die angedeutete Rechnung erhält man Feldgleichungen
von der Form

$$\left.\begin{aligned} G_{\mu\nu} &= -\beta\, \mathfrak{E}_{\mu\nu} - \frac{1}{6}\, i_\mu i_\nu \\ \beta f_{\mu\nu} &= \frac{1}{6}\left(\frac{\partial i_\mu}{\partial x_\nu} - \frac{\partial i_\nu}{\partial x_\mu}\right), \end{aligned}\right\} \quad (12)$$

wobei $G_{\mu\nu}$ wie in (37, 2) den verjüngten Riemann-Tensor bedeutet.
Was nun die physikalische Deutung dieser Gleichungen anlangt,
so hat man jedenfalls $f_{\mu\nu}$ als den Tensor des elektromagnetischen
Tensors zu deuten. Die ~~ersten~~ erste der Gleichungen (12) entspricht genau
den gewohnten Feldgleichungen der allgemeinen Relativitätstheorie in dem hier
in Betracht kommenden Fall, dass ausser dem metrischen Felde
nur ein elektromagnetisches existiert, nur dass noch ein
von der Stromdichte ~~proport~~ bestimmtes energetisches Glied hinzutritt.
Die zweite der Gleichungen (12) scheint der Erfahrung direkt zu wider-
sprechen. Denn sie verlangt, dass das elektromagnetische Feld überall
verschwinde, wo die Ladungsdichte verschwindet.

Dieser Einwand ist jedoch nicht stichhaltig, da wir ja nicht wissen,
ob mit elektr~~ischen~~omagnetischen Feldern nicht sehr kleine elektrische Massendichten verknüpft
sind. Um die Zulässigkeit der Gleichungen (12) beurteilen zu können, müssen
wir ferner berücksichtigen, dass die Einheit des elektromagnetischen Feldes
geändert werden muss, wenn die Länge in cm, die Masse bezw. Energie in Grammen
gemessen werden soll. Wir haben dann anstelle von (12) zu schreiben

$$\left.\begin{aligned} G_{\mu\nu} &= -\beta\alpha^2\, \mathfrak{E}_{\mu\nu} - \frac{1}{6}\,\alpha^2 i_\mu i_\nu \\ \beta f_{\mu\nu} &= \frac{1}{6}\left(\frac{\partial i_\mu}{\partial x_\nu} - \frac{\partial i_\nu}{\partial x_\mu}\right) \end{aligned}\right\} \quad (13)$$

Nach der zweiten dieser Gleichungen existiert ein ~~Vektor~~-Potential Vektor f_μ des elektromagnetischen Feldes $\left(f_{\mu\nu} = \frac{\partial f_\mu}{\partial x_\nu} - \frac{\partial f_\nu}{\partial x_\mu}\right)$ gemäss der Gleichung

$$6\beta f_\mu = i_\mu \quad \cdots (14)$$

Die erste Feldgleichung können wir daher auch schreiben

$$G_{\mu\nu} = -\beta\alpha^2 \mathcal{E}_{\mu\nu} - 6\beta^2\alpha^2 f_\mu f_\nu \quad \cdots (15)$$

Die Existenz praktisch ~~mass~~ strom-freier Felder verlangt gemäss (14), dass β praktisch verschwindend klein sei. Dann wird auch das letzte Glied in (15) verschwindend klein sein gegenüber dem Maxwell'schen Energie-Term. Dann führt unsere Betrachtung zu denselben Feldgleichungen, wie sie von der allgemeinen Relativitätstheorie ursprünglich aufgestellten, die ohne Verallgemeinerung der geometrischen Grundlagen über das Riemann'sche System hinaus gewonnen sind.

Das Elektron als singularitäten-freie Lösung liefern diese Feldgleichungen jedenfalls nicht. Ferner ist von Seiten der Erfahrung bisher kein Anhaltspunkt dafür vorhanden, dass ~~Felder~~ elektromagnetische Felder an ihrem Orte Stromdichten bedingen. Für mich besteht das Endergebnis dieser Betrachtung leider in dem Eindruck, dass uns die Weyl-Eddington-sche Vertiefung der geometrischen Grundlagen keinen Fortschritt der physikalischen Erkenntnis zu bringen vermag; hoffentlich wird die künftige Entwicklung zeigen, dass diese ~~pessimistische~~ Meinung unberechtigt gewesen ist.

A. Einstein.

Bern. 29. IX. 09.

Hoch geehrter Herr Prof. Sommerfeld!

Es drängt mich dazu, Ihnen noch besonders zu danken für Ihre grosse Freundlichkeit. Ganz besonders wird es mir unvergesslich bleiben, wie Sie sich Donnerstag Abend meiner angenommen haben. Es handelte sich übrigens nur um eine kleine Verstimmung meines Magens, den ich durch ganz regelmässiges Leben etwas verwöhnt habe. –

Ich begreife es jetzt, dass Ihre Schüler Sie so gern haben! Ein so schönes Verhältnis zwischen Professor und Studenten steht wohl einzig da. Ich will mir Sie ganz zum Vorbild nehmen.

Die Behandlung des gleichförmig rotierenden starren Körpers scheint mir von grosser Wichtigkeit wegen einer Ausdehnung des Relativitätsprinzips auf gleichförmig rotierende Systeme nach analogen Gedankengängen, wie ich sie im letzten § meiner in der Zeitschr.

f. Radioaktivit. publizierten Abhandlung für gleichförmig beschleunigte Translation) durchzuführen versucht habe.

Ihre Mitteilung, dass der Differenzialquotient der lichtelektrisch gewonnenen Energie nach ν gerade halb so gross sei, als zu erwarten ist, gibt mir sehr zu denken. Wenn sich dies weiterhin als zutreffend erweist, dann ist es nichts mit der Anordnung der Energie des Lichtes um diskrete, mit Lichtgeschwindigkeit ~~be~~ bewegte Punkte. Man wäre genötigt, die Abhängigkeit der Strahlungsentropie vom Gesamtvolumen der Strahlung in anderer Weise zu deuten. Ich bin höchst neugierig, was für eine Genauigkeit jenen Versuchen zukommt.

Es grüsst Sie herzlich

Ihr ergebener A. Einstein.

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Letter from A. Einstein to A. Sommerfeld, dated Bern,
29 September 1909

Esteemed Professor Sommerfeld:

I feel compelled to thank you for your great kindness. In particular I will never forget the way you took care of me Thursday evening. Incidentally, it was merely an upset stomach; it seems that my very regular way of life has apparently pampered my stomach.

I can well understand that your students are so fond of you. Such a wonderful relationship between teacher and students is unique; I certainly want to take you as an example.

The treatment of the uniformly rotating rigid body seems quite important in view of an expansion of the Principle of Relativity to include uniformly rotating systems. I have tried to express similar thoughts in the last paragraph of my treatise on uniformly accelerated straight motion, as published in the Journal for Radioactivity.

I am quite concerned about your statement whereby the differential quotient of the photoelectric energy ν is only exactly one half of what it was to be expected. If this is borne out then it means the end of the arrangement of the energy of light around discreet points moving with the speed of light. One would then be forced to find another explanation for the dependence of the entropy of radiation of the total amount of radiation. I am very curious to learn about the accuray of these experiments.

With cordial greetings,
your devoted
A. Einstein

Nassau Point, den 3.September 1939

Prof. Felix Ehrenhaft
103 Melrose Ave.
Iowa City, Iowa

Lieber Herr Ehrenhaft:

Ich habe nun auch das zweite Manuskript gelesen und finde den Inhalt recht interessant. Nun ein paar offene Bemerkungen zur Sache.

Das Ziel des Experimental-Physikers ist nicht nur, reproduzierbare Erfahrungs-Ergebnisse zu erzielen. Es sollen auch die determinierenden Faktoren so einfach sein aks möglich, damit man Elementargesetze daraus ableiten kann, die man auf andere Situationen anwenden kann.

Wenn wir von diesem Standpunkt die Photophorese ansehen, so erscheinen folgende determinierende Faktoren:

1: Teilchen von bestimmter Substanz (und Ladung?) und bestimmtem Kugelradius.
2: Strahlenfeld mit Strahlrichtung.
3: Inhomogenität des Strahlungsfeldes.
4: Natur und Dichte des umgebenden Gases.

Würde die auf das Teilchen wirkende Kraft von allen 4 Faktoren wesentlich abhängen, so hätten wir ein Phänomen vor uns, dessen kausale Analyse nahezu hoffnungslos kompliziert wäre. Leider scheint es, dass Punkt 4) wesentlich ist. Wenigstens wird dies bezüglich der Gasdichte behauptet, die sogar für das Vorzeichen des Effektes in manchen Fällen massgebend sein soll. Ob es wirklich sicher ist, dass 3) einen Einfluss hat, weiss ich nicht. Auch dies würde die Aussichten auf eine Erkenntnis der wesentlichen Faktoren wesentlich erschweren. Punkt 4) ist aber am bedenklichsten im Hinblick auf eine einigermassen einfache Deutung des ganzen Phänomens, weil er die molekularen Zusammenstösse mit dem Teilchen als wesentlich erscheinen lässt Nicht nur die Temperatur-Differenzen sondern auch jene des statistischen Winkel-Gesetzes für den Zusammenstoss kämen in Betracht, und das Phänomen würde als überaus komplizierter radiometrischer Effekt aufzufassen sein.

2- Prof.Ehrenhaft, Iwoa City. 3.9.39

Was auf mich den meisten Eindruck gemacht hat, das ist die zusätzliche Kraft, die durch schwache transversale Magnetfelder erzeugt wird. Dies riecht mehr nach etwas Elementarem. Man sollte jedenfalls herauszubringen versuchen, ob auch dieser Effekt von Natur und Dichte des Gases abhängt. Wenn es nicht der Fall wäre, würde es mit den ~~xxxxxxxxxx~~ gegenwärtigen physikalischen Ideen bestimmt keine Erklärung geben. Würde aber der Gaseinfluss dominieren, so würde es sich auch hier wohl um einen durch einen komplizierten Zwischenvorgang (Rotation des Teilchens?) mit bedingten radiometrischen Prozess handeln.

Noch zwei Bemerkungenx über Einzelheiten: Sie sprechen an mehreren Stellen von einem ungeladenen Teilchen; ein solches würde es nach Ihrem allgemeinen Standpunkt gar nicht geben, da es ein unendlich unwahrscheinlicher Grenzfall wäre. Es scheint also, dass Sie den in der ersten Arbeit vertretenen Standpunkt in Ihrem "Unbewussten" selber nicht ernst nehmen.- Ihre Andeutung, man solle neue Feldtheorien zur Erklärung der in der Arbeit untersuchten Phänomene anwenden, wirkt ohne Andeutung darüber, wie dies geschehen soll, einfach lächerlich; Vergleich: es macht einer den Vorschlag, man solle die Kursschwankungen auf der Börse aus den Maxwell'schen Gleichungen herzuleiten versuchen.

Freundlich grüsst Sie

Ihr

A. Einstein.

P.S. Dies alles ist roh ausgedrückt und brutal, damit es klar hervortrete. Dies steht nicht im Widerspruch damit, dass mir der Inhalt der Arbeit recht interessant erscheint.

A letter from Supreme Court Justice Benjamin Cardozo, 1932, congratulating Dr. Abraham Flexner, secretary of the Carnegie Foundation and the Director of the Institute for Advanced Studies on the "capture" of Dr. Einstein for the faculty of the Institute.

B. N. Cardozo

2101 Connecticut Av.

Supreme Court of the United States
Washington, D.C.

Oct. 11, 1932

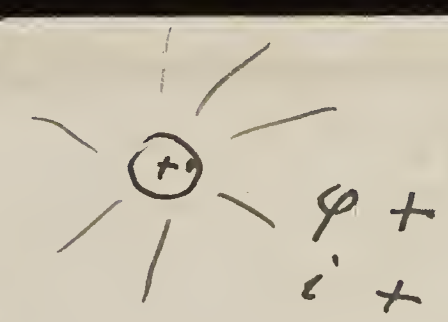
Dear Dr. Flexner,

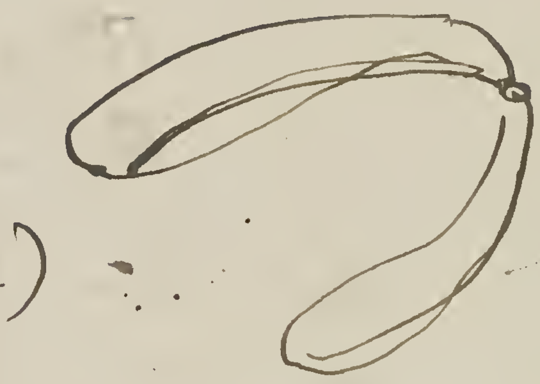
I have read with delight that Einstein has been captured for the faculty of the Institute.

From my exile in Washington I send you congratulations and kindliest greetings.

Faithfully yours,
Benjamin N. Cardozo

Dr. Abraham Flexner





1.) Hamilton? (Feld) ..

2.) Formal ⇒ Content.

3.) Quantum → Überbestimmung – mehr Gleich → für wenig Unbekannte – dies fundamental Antihamiltonsches.

4) $\text{Theorie} = \left(A \overset{\to \cancel{\text{Defin}}\ \text{Content}}{+} \underbrace{B + C + D}_{\text{Content}}\right)$

$$C_\mu^{\ \nu} - \frac{1}{2}\delta_\mu^{\ \nu} C = -8\pi \left(F_{\mu\sigma} F^{\nu\sigma} + \dots\right) + \dots$$

5.) $J^\mu = T^{\mu\nu}_{\ \ \nu}$

$J^\mu_\mu = 0$ $\qquad J_\mu^\nu = \frac{\partial K}{\partial g_{\mu\nu}}$

6.) $\frac{\partial}{\partial \Gamma^\alpha_{\mu\nu}}$ vieldeutige Natur.

$$\delta A^{\mu} = - \Gamma^{\mu}_{\sigma\tau} A^{\sigma} \delta x_{\tau}$$

symmetrisch

$R^{\mu}{}_{i\kappa\sigma}$ Tensor

R_{ik} Tensor

| Bemerkung
$R_{\kappa\sigma} \approx \varphi_{\kappa\sigma}$

$$\left.\begin{aligned} \gamma_{ik} &= \tfrac{1}{2}(R_{ik} + R_{ki}) \\ \varphi_{ik} &= \tfrac{1}{2}(R_{ik} - R_{ki}) \end{aligned}\right\} (1)$$

$$\mathfrak{H}(\gamma_{ik};\varphi_{ik})$$

$$\int \Big(\underbrace{\frac{\partial \mathfrak{H}}{\partial \gamma_{ik}}}_{\mathfrak{g}^{ik}} \delta\gamma_{ik} + \underbrace{\frac{\partial \mathfrak{H}}{\partial \varphi_{ik}}}_{\mathfrak{f}^{ik}} \delta\varphi_{ik} \Big) = 0$$

| $\dfrac{\partial \mathfrak{f}^{\sigma\kappa}}{\partial x_{\kappa}} = i^{\sigma}$

Variation liefert 40 Gleichungen, die auflösbar

$$\Gamma^{\sigma}_{\mu\nu} = \left\{ {\mu\nu \atop \sigma} \right\} - \tfrac{1}{2} i^{\sigma} g_{\mu\nu} + \tfrac{1}{6} i_{\mu} \delta^{\sigma}_{\nu} + \cdot \qquad (2)$$

Herr Weyl verlangt (einmal) dass

$$\gamma_{ik}\, \delta\mathfrak{g}^{ik} + \varphi_{ik}\, \delta\mathfrak{f}^{ik} = \delta \mathfrak{H}^{x}(\mathfrak{g}^{ik}, \mathfrak{f}^{ik})$$

$$\left.\begin{aligned} \gamma_{ik} &= \frac{\partial \mathfrak{H}^{x}}{\partial \mathfrak{g}^{ik}} \\ \varphi_{ik} &= \frac{\partial \mathfrak{H}^{x}}{\partial \mathfrak{f}^{ik}} \end{aligned}\right\} (3)$$

(2) und (3) in 1 eingesetzt, wodurch die Γ eliminiert werden.

$$\mathfrak{H}^{x} = -\tfrac{1}{2} g_{\alpha\sigma} g_{\beta\tau} \mathfrak{f}^{\alpha\beta} \mathfrak{f}^{\sigma\tau} \cdot \frac{1}{\sqrt{g}}$$

Endgl. bedeuten

$$R^{x}_{ik} = -\kappa (T^{x}_{ik\,el.} + \beta f_i f_k)$$

$$i^{x}_{\alpha} = -\beta f_{\alpha}$$

Einstein
etwa 1925

DSI

ALBERT EINSTEIN

BERLIN W. den 18. September 1930
HABERLANDSTR. 5
Caputh b.Potsdam,Waldstr.7/8

Herrn Dr.ing.Armin Weiner
B r ü n n, C.S.R.
Nova 36
\- - - - - - - - - - - - - - - -

Sehr geehrter Herr!

Ich danke Ihnen herzlich für die Uebersendung des ungemein interessanten Mach'schen Briefes, den ich mit Ihrer Erlaubnis behalte. Einen irgendwie bedeutsamen Briefwechsel mit Mach hatte ich nicht. Wohl aber hat Mach durch seine Schriften auf meine Entwicklung erheblichen Einfluss gehabt. Ob,bezw.in wie weit meine Lebensarbeit dadurch beeinflusst wurde, ist mir selber unmöglich,herauszufinden. Mach hat sich in seinen letzten Jahren mit der Relativitätstheorie befasst und sich sogar in einer Vorrede zu einer späteren Ausgabe eines seiner Werke ziemlich schroff ablehnend gegen die Relativitätstheorie ausgesprochen. Es kann aber kaum einen Zweifel unterliegen, dass dies eine Folge von durch das Alter verminderter Aufnahmefähigkeit gewesen ist, da die ganze Denkrichtung dieser Theorie der Mach'schen konform ist, so dass Mach mit Recht als Vorläufer der allgemeinen Relativitätstheorie betrachtet wird. Ich habe dies in einem Ernst Mach gewidmeten Aufsatz erwähnt, der vor vielen Jahren in den "Naturwissenschaften" erschienen ist.

Freundlich grüsst Sie

Ihr

A. Einstein.